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# Proceedings: Western Forest Nursery Council- Intermountain Nurseryman's Association

## Combined Meeting

August 14-16, 1984  
Coeur d'Alene, Idaho

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**COVER PHOTO:** Innovations at forest tree nurseries enhance quality of the product and conserve time and funds. This cart used at Bend Pine Nursery, Bend, OR, was constructed to spread protective net over newly sown conifer seed beds. Labor savings paid for the cart in one season.



# **Proceedings: Western Forest Nursery Council- Intermountain Nurseryman's Association Combined Meeting**

**August 14-16, 1984  
Coeur d'Alene, Idaho**

**Compiled by:  
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## **Acknowledgments**

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PLUG SEEDLING SUCCESS IN THE HIGH COUNTRY //

Steve L Altsuler

**ABSTRACT:** This paper discusses the success of container seedling outplantings in the high country of Southwestern Oregon over the last several years. A brief history of Weyerhaeuser's plug seedling production is also presented.

## INTRODUCTION

Weyerhaeuser Company went into plug seedling production with a bang in the early seventies. The early plug was seen as a panacea that would quickly revolutionize the entire regeneration business. Plugs were prescribed rather indiscriminately without much regard to site index or economic evaluation. Demand ballooned to the point that all three of Weyerhaeuser's greenhouse facilities on the west coast were scheduled for double cropping. This system required early (February or March) sowing and, in June, moving the first crop out to a holding area followed by resowing the germination houses with a second crop. Both crops were outplanted in the spring.

During the mid-seventies, economic evaluation of stock type and site index began to modify seedling orders. Prescription of stems per acre dropped across the board, and bareroot stock began to rapidly replace the relatively expensive plug stock. By 1977, Weyerhaeuser had permanently closed one greenhouse facility, mothballed a second, and lumped all remaining plug orders into the third facility. This enabled us to start producing one crop per year and it also allowed us to begin growing stock for outside customers under contract.

One of our biggest plug customers since then has been the National Forests of the western United States. Over eight million containerized seedlings have been shipped by Weyerhaeuser to the National Forests of the Pacific Northwest over the last 5 years. Species involved have been numerous including Douglas-fir, noble fir, white fir, Shasta red fir, ponderosa pine, sugar pine, western white pine, and Englemann spruce.

## USE AND SURVIVAL

The experience with these plugs at Rogue River, Umpqua, and Siskiyou National Forests has been

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typical of the success our customers have experienced, both within and outside the company. For the last several years these forests have typically prescribed plugs for hard to regenerate, problem sites. Elevations usually run between 3,000-5,500 feet (914 to 1 670 m) and soils are typically very shallow and skeletal in nature. Sometimes particular species are matched with adverse environmental conditions, for example, Englemann spruce in wet low lands. Some units were bareroot failures in which planting quality in shallow rocky soils presumably had been a problem, hence they were rescheduled for plug stocking. The foresters provided district-wide comparisons between first-year survival of plug seedlings and bareroot stock. This information is summarized in table 1.

These data do not represent side-by-side stock comparisons, but rather survival plots in the widely scattered units. Plug stock generally went to sites that would have been difficult to properly plant bareroot stock in. The foresters were convinced that side-by-side trials would have favored plug survival even more than table 1 data indicate.

The main thing this table shows is the consistent performance of the plug seedlings. Whereas the plug stock didn't always outperform the bareroot stock, it consistently had excellent survival. This is extremely critical when you consider experiences like the one at Siskiyou last year, where the 58 percent survival of bareroot Douglas-fir was an average over 963 acres. The preliminary survival plot data indicated that 396 acres would have to be replanted in 1984!

Table 1.--First-year survival comparisons -- plug vs. bareroot

Forest	Year	Species	Stock Type	1st Year Survival Percent
Umpqua	1982	Douglas-fir	Plug	92
Umpqua	1982	Douglas-fir	Bareroot	88
Umpqua	1982	Shasta red fir	Plug	95
Umpqua	1982	Shasta red fir	Bareroot	83
Umpqua	1982	Lodgepole pine	Plug	97
Umpqua	1982	Lodgepole pine	Bareroot	93
Umpqua	1982	White sugar pine	Plug	88
Umpqua	1982	White sugar pine	Bareroot	95
Umpqua	1982	White fir	Plug	100
Umpqua	1982	White fir	Bareroot	60
Rogue River	1982	White fir	Plug	92
Rogue River	1982	White fir	Bareroot	92
Rogue River	1982	Shasta red fir	Plug	92
Rogue River	1982	Shasta red fir	Bareroot	97
Rogue River	1982	Engleman spruce	plug	96
Rogue River	1982	Engleman spruce	Bareroot	80
Siskiyou	1983	Douglas-fir	Plug	96
Siskiyou	1983	Douglas-fir	Bareroot	58
Umpqua	1983	Shasta red fir	Plug	94
Umpqua	1983	Shasta red fir	Bareroot	78



## PLANTATION SCENES

The following are some scenes from slides taken on field tours to the plantations in 1980, 1982, and 1983. They rather descriptively portray the field results and are typical of the success we have realized in these relatively hard to regenerate sites.



Figure 1.--Umpqua, 1980. Ponderosa pine plug seedling plantation after one season's growth (planted in spring, photographed in August). This unit had been planted with 2+0 Douglas-fir in 1978, but required restocking due to poor survival.



Figure 2.--Same site as fig. 1, 1982. Ponderosa pine pushing waist high.



Figure 3.--Same site as fig. 1, 1983. Plantation approaching shoulder high after four growing seasons.



Figure 4.--Rogue River, 1980. White fir shade card plantation. One season's growth.



Figure 5.--Same site as fig. 4, 1982. White fir pushing waist high.





Figure 6.--Rogue River, 1980. White fir "Rock Pile" plantation. One season's growth.



Figure 7.--Rogue River, 1982. White fir "Rock Pile" plantation. One season's growth.



Figure 8.--Rogue River, 1983. Englemann spruce - rocky wet land plantation. Two seasons' growth. Note root egress.

#### PRESSURES ON STOCK

The pressures put on this plug stock have essentially come from two sources. Animal damage is probably the most severe with deer browse causing most of the damage. Some insect girdling has also been noticed. Installation of vexar tubing has been quite successful in protecting the seedlings from deer browse, particularly at Umpqua National Forest. The second source of pressure has been sun scalding or heat girdling at ground line. The Forest use of shade cards, micro-site planting, and shelter wood units has minimized damage from scalding, but it needs to be noted that higher density type plugs (leach pine or styro-2) can be quite sensitive to heat damage because of their smaller stem caliper.

This report has referred to comparisons between bareroot stock and plug seedlings, and it should be noted that all bareroot stock involved has been 2+0 seedlings. Survival of transplants might be more appropriate to compare with plug seedlings, but in the soil types discussed planting quality of large root systems could present even greater problems. The experience in the Southwestern Oregon high country of these three National Forests very closely matches that of our own company units in the same geographic area. Plug seedlings for us have also proven to be reliable performers in the shallow skeletal soils common in this region.



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EFFECTS OF CONTAINER SIZE ON WHITE PINE AND DOUGLAS-FIRSURVIVAL AND GROWTH IN NORTH IDAHO

Daniel L. Miller and Richard M. Schaefer III

ABSTRACT: This study was designed to determine the effect container size has on field survival and growth of western white pine (*Pinus monticola*) and Douglas-fir (*Pseudotsuga menziesii*). Between 1978 and 1982 field tests were installed in 13 plantations, and height growth and survival of styro-2, 4 and 8 seedlings were tracked for 2 to 5 years. Results indicate that styro-2 white pine survived as well as larger seedlings although height growth was slightly less. Greenhouse disease problems currently prevent growing operational quantities of styro-2 white pine, however. Styro-2 Douglas-fir performed as well as styro-4 seedlings on most sites. Styro-2 seedlings may be used on all but the driest Douglas-fir sites. In general, styro-8 seedlings were larger when planted and produced better height growth than styro-2 or 4 white pine and Douglas-fir seedlings. Increased survival and growth did not compensate for increased styro-8 production costs, however.

styro-4 seedlings (table 1). In addition to seedling production costs, survival and growth data are needed to determine which container size results in lowest cost per surviving, healthy seedling.

Table 1.--Container size descriptions and production cost comparison

Container	Cavities/ Sq. Ft.	Cavity Size (cu.in.)	Cavity Depth (in.)	Percent Cost/M Change
Styro-2	96	2.5	4.5	-36
Styro-4	63	4.8	5.0	0
Styro-8	41	8.0	6.0	+149

This study was designed to determine the effects that container size has on field survival and growth of western white pine and Douglas-fir seedlings.

## METHODS

Between 1978 and 1982 container size tests were installed in 13 plantations. These planting sites were selected to test the effects of north and south slopes (moister and drier sites) on survival and growth. White pine and Douglas-fir grown in styro-2, 4, and 8 containers were planted in 1978, 1979, and 1980. In 1980 only styro-2 and 4 containers were used for white pine.

Seedlings were grown one summer in the greenhouse. Seed was sown in March and height growth was completed in August. Seedlings were hardened off during the fall and shipped to cold storage in February. They were removed from storage and planted in May. Seedlings were held in the styro-blocks until planted.

The 1978 and 1979 tests consisted of three blocks planted on each site for each species tested. Each block contained a row of 25 seedlings of each container size planted 2 feet apart with 2-3 feet between rows. Tests planted in 1980 and later consisted of four blocks of each species on each site. Each block was a row of 20 seedlings planted 4-6 feet apart with rows 6-10 feet apart. This wider spacing will allow tracking growth for more than 5 years before inter-tree competition becomes severe. Earlier tests were spaced tighter

## INTRODUCTION

In a containerized seedling production greenhouse, container size affects both seedling size and production costs. Larger containers provide increased space for both shoots and roots. This will usually be reflected in seedling size. In general, larger containers produce taller seedlings with larger stem diameters than do smaller containers (Miller 1978). Seedling stem diameter at the soil line may be critical to seedling establishment. Smaller stems are more susceptible to girdling by high temperatures at the soil surface (Cleary and others 1978). Larger seedlings have more insulating tissue that shields sensitive cambial cells. This is especially important on hot dry sites.

Container size is also an important component of seedling cost. The cost of producing containerized seedlings is largely governed by seedling density. Growing more seedlings per square foot of greenhouse space reduces the fixed cost per seedling. For example, seedlings grown in styro-2 containers cost 36 percent less to grow than

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as significant survival differences were expected and uniformity of microsite was the major concern. All seedlings were dibble-planted. Initial height (the distance from the cotyledonary node to the base of the terminal bud or candle) was measured following planting. Subsequent annual height growth increments were measured and survival and injury recorded.

Frost and animal damage severely affected the Little Green Mtn. test. As a result, only second year data are reported. Similarly, second year results of the Shanghai 1978 test are reported for Douglas-fir and third year data for white pine.

Total height and survival data were analyzed by analysis of variance for each site separately. All animal-damaged seedlings (browsed, clipped) were eliminated from the analyses since the plots were not designed to accurately evaluate animal damage. Means were ranked using Duncan's multiple range test when significant treatment (container) differences were detected.

Where measured total heights were significantly different between container sizes, regression techniques were used to estimate the years required to reach 15 feet (4.5m) tall. Differences in years to 15 feet were assumed to indicate potential rotation length differences. This assumes that trees grown in different containers will all grow similarly after they reach 15 feet tall. By then only site quality and inter-tree competition should be limiting growth.

## RESULTS AND DISCUSSION

### Western White Pine

With the exception of Little Green Mountain, container size did not significantly affect survival (table 2). The styro-2 survival at Little Green Mtn. did not differ from styro-8 survival, but was significantly better than styro-4 survival. No reason for this difference is apparent. Survival was poor (48-49 percent) for both styro-2 and styro-4 containers at Robinson Creek. This test was planted on a southwest aspect where soil was thin and rocky. This was a relatively severe site, but the larger container size produced no increase in survival. All other sites produced survival in excess of 90 percent for all container sizes.

Based on plantation establishment costs of planting 500 seedlings per acre (1 235/ha), survival of styro-4 seedlings would have to be at least 20 percent higher than survival of styro-2 seedlings to justify planting the more expensive seedlings. If the expected survival difference is less than 20 percent, it costs less to plant additional styro-2 seedlings to compensate for mortality. If white pine survival was the only basis for selecting container size, the lack of significant differences would suggest that we should use styro-2 stock on all sites.

Total height varied significantly on several sites (table 2). Styro-2 seedlings were significantly shorter than styro-4 seedlings in the Breakfast Creek 1978 test. Height growth projections indicated that there will be no significant difference in estimated rotation age, however. Both styro-2 and styro-8 heights differed significantly from the styro-4 height in the Orogrande Creek 1979 test. Estimated rotation ages also differed; with the styro-2 trees taking 1 more year and the styro-8 trees 1 year less to reach maturity than the styro-4 trees. Economic analysis of planting cost and rotation length changes indicated no significant value difference at maturity. At the Robinson Ridge site, styro-8 seedlings were taller after 5 years and are estimated to take 1 less year to reach rotation than styro-4 seedlings. Increased styro-8 seedling production costs more than offset the economic advantage of a shorter rotation, however.

Styro-4 seedlings were significantly taller than styro-2 seedlings at Elk Creek, Potato Hill, and Stoney Creek after 3 years (table 2). These differences resulted in a rotation length change only at Potato Hill where styro-2 seedlings lengthened rotation by 1 year, but still increased plantation value slightly.

### Douglas-fir

With the exception of the Little Green Mountain and Mt. Margaret sites, survival did not vary significantly by container size (table 3). Styro-2 survival at the Breakfast Creek 1979 site averaged 35 percent below that of styro-4 seedlings. A significant difference was not detected due to variation in survival between blocks on the site, however. Styro-2 survival was much lower on two blocks, but about equalled styro-4 survival on the third. Given this and the size of the difference, we should assume that there is an increased risk associated with planting styro-2 containers at Breakfast Creek and styro-4 seedlings should be selected. Based on plantation establishment costs and planting 400 Douglas-fir seedlings per acre (988/ha), styro-4 survival must exceed styro-2 survival by 14 percent to cover increased stock costs. If the expected difference is less than 14 percent, it costs less to plant more styro-2 seedlings to compensate for increased mortality. Similarly, planting styro-8 seedlings must increase survival by at least 15 percent over that of styro-4 seedlings to cover increased seedling production costs.

Based on survival differences, we should select styro-4 Douglas-fir over styro-2 seedlings only on dry sites with shallow or rocky soil such as Mt. Margaret where styro-4 containers increased survival by 22 percent. Styro-8 containers did not increase survival enough on any site to justify their use. Severe sites where styro-8 containers would prove beneficial are best planted to more drought-resistant species such as ponderosa pine.



Table 2.--White pine survival and total height by site and container size. Browsed and clipped seedlings were deleted from analyses. Figures within site followed by different letters are significantly different ( $\alpha=0.05$ ). Figures not followed by letters do not differ significantly

Site	Year Planted	Slope/ Aspect	Site Index <sup>1</sup>	Precip. (in.)	Elev. (ft.)	Site Prep	Survival (%)			Total Height (in.)		
							Styro-2	Styro-4	Styro-8	Styro-2	Styro-4	Styro-8
----- FIVE-YEAR DATA <sup>2</sup> -----												
Orogrande Cr.	1978	40/N	101	45	4000	Dozer	98	98	100	30 b	31 ab	33 a
Breakfast Cr.	1978	10/N	108	45	4200	Dozer	93	100	98	25 b	29 a	29 a
Orogrande Cr.	1979	20/NW	101	45	4200	Dozer	100	100	100	25 c	32 b	36 a
Shanghai	1979	25/S	67	40	4100	Dozer	95	91	97	22	22	25
Robinson Ridge	1979	40/N	86	45	3800	Burn	98	98	100	30 b	33 b	38 a
Breakfast Cr.	1979	30/S	90	45	4200	Dozer	98	98	97	26 b	27 ab	29 a
----- THREE-YEAR DATA -----												
Shanghai	1978	25/SE	67	40	4200	Burn	91	92	94	10	11	11
Elk Cr.	1980	30/S	83	50	4000	Dozer	90	93	--	17 b	20 a	--
Potato Hill	1980	35/NW	79	45	4000	Dozer	98	99	--	17 b	21 a	--
Stoney Cr.	1980	65/NE	119	45	3000	Burn	99	100	--	16 b	20 a	--
Robinson Cr.	1980	20/SW	88	40	3500	Burn	49	48	--	7	8	--
----- TWO-YEAR DATA -----												
Little Green Mtn.	1978	10/S	93	45	4700	Dozer	94 a	87 b	89 ab	5 b	7 a	6 ab

<sup>1</sup>@ 50 years breast height, calculated, not measured.

<sup>2</sup>Time since planting.

Table 3.--Douglas-fir survival and total height by site and container size. Browsed and clipped seedlings were deleted from analyses. Figures within site followed by different letters are significantly different ( $\alpha=0.05$ ). Figures not followed by letters do not differ significantly

Site	Year Planted	Slope/ Aspect	Site Index <sup>1</sup>	Precip. (in.)	Elev. (ft.)	Site Prep	Survival (%)			Total Height (in.)		
							Styro-2	Styro-4	Styro-8	Styro-2	Styro-4	Styro-8
----- FIVE-YEAR DATA <sup>2</sup> -----												
Orogrande Cr.	1978	40/N	101	45	4000	Dozer	100	100	100	41 b	43 b	48 a
Breakfast Cr.	1978	10/N	108	45	4200	Dozer	95	97	100	41 b	48 ab	53 a
Orogrande Cr.	1979	20/NW	101	45	4200	Dozer	98	98	100	34 b	34 b	44 a
Shanghai	1979	25/S	67	40	4100	Dozer	77	81	92	24 b	27 b	35 a
Robinson Ridge	1979	40/N	86	45	3800	Burn	100	93	97	33	33	36
Breakfast Cr.	1979	30/S	90	45	4200	Dozer	50	85	78	14 b	27 a	28 a
----- THREE-YEAR DATA -----												
Elk Cr.	1980	30/S	83	50	4000	Dozer	100	94	96	22	22	24
Potato Hill	1980	35/NW	79	45	4000	Dozer	84	78	91	13 b	13 b	16 a
Stoney Cr.	1980	65/NE	119	45	3000	Burn	99	99	100	19 b	21 a	22 a
Robinson Cr.	1980	20/SW	88	40	3500	Burn	72	73	82	15	15	18
----- TWO-YEAR DATA -----												
Shanghai	1978	25/SE	67	40	4200	Burn	86	87	100	15	14	18
Little Green Mtn.	1978	10/S	93	45	4700	Dozer	82 b	85 b	98 a	9 b	11 b	14 a
Mt. Margaret	1982	20/NE	87	40	3900	Dozer	52 b	74 a	77 a	5 b	12 a	12 a

<sup>1</sup>@ 50 years breast height, calculated, not measured.

<sup>2</sup>Time since planting.



Styro-2 seedlings produced significantly less height growth than styro-4 seedlings on only three sites (table 3). Styro-2 seedlings were 13 inches (32.5 cm) shorter than styro-4 seedlings at the Breakfast Creek (1979) site. This difference only lengthened the predicted rotation age by 1 year, but the less expensive seedlings offset the cost of the longer rotation. Survival differences would not favor planting styro-2 seedlings on this site, however. Three-year height differences at Stoney Cr. also resulted in a 1 year longer rotation for styro-2 seedlings. The 1 year height data from Mt. Margaret couldn't be analyzed for rotation length differences, but survival data. favored styro-4 seedlings.

Styro-8 seedlings were significantly taller than styro-4 seedlings on five test sites. Planting styro-8 rather than styro-4 seedlings on these sites shortened the predicted rotation length by 1 year, but resulted in reduced net present values due to higher seedling costs.

#### CLIMATIC CONDITIONS

Growing season precipitation during 3 of the 5 years that tests were planted was at least 25 percent above normal (table 4). Even in drier years, July or August precipitation was above normal. The increased precipitation may have reduced stress during the critical first year of seedling establishment. Had the climate been in a dry cycle, survival results may have differed slightly.

Table 4.--Growing season precipitation recorded at Pierce, Idaho (National Oceanic and Atmospheric Administration data)

Month	Normal Precip. (in.) <sup>1</sup>	Percent of Normal				
		1978	1979	1980	1981	1982
May	3.51	122	164	138	118	52
June	3.47	63	29	135	210	81
July	1.03	340	36	122	187	315
Aug.	1.14	219	135	128	50	65
Sept.	2.34	73	20	139	98	92
TOTAL	11.49	124	80	135	141	93

<sup>1</sup>Average of 1941-1970 precipitation.

#### GREENHOUSE PRODUCTION CONSIDERATIONS

Both species examined in this test have been produced in operational quantities in styro-4 containers. Styro-2 containers pose some operational concerns due to increased seedling density which reduces the amount of light available to the seedlings, increasing suppression problems. Suppressed seedlings generally won't reach plantable size in styro-2 containers. Also, the increased density retards foliage drying following

irrigation. This, combined with dead needles that have died from shading, produce increased disease risks. The following comments address these and other concerns that make greenhouse production of styro-2 seedlings more difficult.

#### Western White Pine

We have not grown white pine on a production basis in styro-2 containers. Seedlings planted in these research tests were grown in less than a dozen blocks. This is not a large enough size to sample microclimate effects which influence disease occurrence in the greenhouse or to provide a large mass of densely grown seedlings which also affects disease impact. White pine has been operationally grown in styro-4A blocks. These have 87 cavities/ft<sup>2</sup> compared to 96 cavities/ft<sup>2</sup> for styro-2 blocks. Observations based on styro-4A production are as follows:

- 1) Five percent were culled during pull-and-wrap operations due to poor caliper development.
- 2) Mortality increased an additional 5 percent due to botrytis (grey mold) infections. Usually the smaller codominant and intermediate seedlings were affected.
- 3) Styro-2 production could increase disease control chemical cost by \$3/M over that for styro-4 production. Increased control activities still may not reduce disease incidence.

If these observations hold true for the denser styro-2 seedlings, then production costs could increase by 14 percent. This still leaves a 28 percent cost difference between styro-2 and 4 seedlings, however.

#### Douglas-fir

Large lots of Douglas-fir have been operationally grown in styro-2 containers. The following observations are based on this experience:

- 1) A 3-5 percent reduction in shippable (or plantable) seedlings results from the increased competition in styro-2 containers.
- 2) Styro-2 containers have not increased disease problems.
- 3) Styro-2 sowings use approximately 15-20 percent more seed than styro-4 sowing. Extra seed is used to ensure rapid and uniform germination in all cavities. Late germinating seedlings are often suppressed due to increased competition (seedling density) for light and may never reach plantable size.

## CONCLUSIONS

Data from 11 sites indicate that planting styro-2 rather than styro-4 white pine will not result in reduced survival. Where 3- or 5-year total heights differed significantly, further analyses indicated that no practical differences existed between styro-2 and styro-4 seedling growth. Based on survival and growth data, white pine should be grown in styro-2 containers. Greenhouse problems may preclude styro-2 production, however. Increased risk of disease mortality must be evaluated before beginning large scale styro-2 production.

Douglas-fir survival data suggest that styro-4 containers may be needed only on the driest sites. Styro-2 seedling performance was excellent on moister sites. Height growth differences did not justify using larger containers. The slight increase in height and decrease in predicted rotation lengths produced by larger containers did not compensate for the increased seedling production costs.

Seedling root growth was not examined in this study. Although root development problems are not anticipated, examinations should be made to determine if root form problems may develop.

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PHOTOPERIOD CONTROL OF CONTAINER SEEDLINGS //

James T. Arnott

**ABSTRACT:** Research at the Pacific Forest Research Centre, Victoria, on the use of photoperiod lighting to grow seedlings of white spruce, Engelmann spruce, white x Engelmann hybrids, mountain hemlock, and amabilis fir in container nurseries is reviewed. Factors investigated were the critical minimum and maximum light intensities required by the above species when using photoperiod lighting; comparisons of natural daylength extension and cyclic lighting (interruption of the darkness); the effect of photoperiod lighting failure on tree seedling growth; and the influence that photoperiod lighting in the nursery has on tree seedling growth in the following year.

#### INTRODUCTION

The effect of photoperiod on the growth of tree seedlings has been known for some time and has been reviewed by Arnott and Mitchell (1981). The objective of this presentation is to highlight some of the results of research conducted at the Pacific Forest Research Centre (PFRC) to provide operational guidelines for container nursery growers in British Columbia (B.C.) using photoperiod lighting to grow tree seedlings.

Throughout this report, photometric units (lux) will be used to define light intensity levels (1 ft-candle = 10.8 lux). However, lux is not a measure of radiation received by plants but a measure of visible radiant energy that has spectral sensitivity (i.e., 200 lux from an incandescent source is not equivalent to 200 lux from a high pressure sodium (HPS) source). Therefore, when applying results from these and other studies, the reader must consider the source of lighting used.

#### EXTENDED DAYLENGTH VERSUS CYCLIC LIGHTING

In the coastal region of southwestern B.C. the long growing season is advantageously used to produce northern provenances of white spruce

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(*Picea glauca* [Moench] Voss), and high-altitude species such as Engelmann spruce (*Picea engelmannii* [Parry]), mountain hemlock (*Tsuga mertensiana* [Bong.] Carr.), and amabilis fir (*Abies amabilis* [Dougl.] Forbes). However, north-latitude and high-altitude ecotypes have long critical daylengths (Habj rg 1972; Heide 1974). Unless seedlings of these species growing in southern B.C. nurseries are provided with an extended photoperiod, they prematurely form terminal buds, cease shoot growth early in the season, and do not achieve the desired height (Arnott 1974, 1979).

Trees can be kept in a state of indeterminate growth by extending the daylength with low-intensity artificial light or by interrupting the dark period with light of low intensities (cyclic lighting). Experiments at PFRC determined the duration of dark period interruption required in cyclic lighting to maintain growth of the four species listed above and compared such treatments with the growth response obtained using extended daylengths in an outdoor container nursery at Victoria, B.C. (lat. 48°28'N). Details have been published elsewhere (Arnott 1974), and have been presented at a meeting of this Nursery Council (Arnott 1976). Height growth of all four species was significantly greater under the extended daylength and cyclic lighting treatments than in the control where seedlings started forming terminal buds as early as mid-May. Supplemental photoperiodic light prevented early terminal bud formation. Cyclic lighting of 2 minutes every 30 minutes of darkness produced seedlings of white spruce, Engelmann spruce, and mountain hemlock that were significantly taller than those grown under the 18-h extended photoperiod. Amabilis fir seedlings grown under the 18-h regime were taller than those grown under cyclic lighting.

#### LIGHT INTENSITIES FOR EXTENDED PHOTOPERIOD

##### Critical Minimum

Most nursery growers are interested in knowing what the critical minimum light intensities are for species that require daylength extension. Critical minimum is defined as the minimum intensity of supplemental photoperiodic lighting required to produce seedling shoot lengths that are significantly larger than seedlings grown under natural photoperiods. These intensities were determined

for white spruce, Engelmann spruce, mountain hemlock, and amabilis fir (Arnott 1979). The experiment was conducted in situ at the Koksilah tree nursery (latitude 48°47'N) at Duncan, B.C., to provide some answers for local nurserymen. A 400-watt, high-pressure sodium (HPS) lamp was chosen as the supplemental light source for extending the photoperiod to 24 h. The treatment stations were positioned along the length of the shadehouse nursery at 20-foot (6-m) intervals in a direct line away from the light source to provide the following light intensities.

Distance from Light Source		Supplemental Light Intensity
(ft)	(m)	(lux)
20	6	220
40	12	80
60	18	40
80	24	20
100	30	12
120	36	8
140	42	5
-	-	0

Terminal resting buds were noted and seedling height was recorded biweekly throughout the experiment until October 30, when a destructive sample was taken for shoot and root dry weight.

Extending the photoperiod and increasing the light intensity had highly significant effects on seedling shoot growth of all four species (fig. 1). Shoot length and weight declined as the light intensity decreased. The effect of extended photoperiod and increasing light intensity on root weight was usually negative, although the differences were significant only in two spruce seedlots. The greatest shoot length response to light intensity was attained at the highest level (220 lux). The critical minimum intensity varied by species as follows.

Species	Critical minimum for HPS source (lux)
White spruce	80
Engelmann spruce/ White-Engelmann hybrid	40
Engelmann spruce	20
Amabilis fir	20
Mountain hemlock	80

The trend in shoot weight was somewhat different. Minimum light intensity levels usually had to be one treatment level higher to produce a response significantly different from that of the controls. The smaller average shoot length and weight at the lower light intensities is a result of many of the seedlings forming terminal resting buds and ceas-

ing shoot growth before the lights were turned off on September 7.

Species differ in their response to light intensities used to extend the photoperiod. Amabilis fir did not respond dramatically to the various levels of light intensity. This confirms earlier work where that species showed a small but significant response to extended photoperiodic treatment; in that case, using a light intensity of 1600 lux from an incandescent source (Arnott 1976). Mountain hemlock and the spruces made large gains in shoot growth at the higher light intensities.

#### Critical Maximum

Having determined the minimum light intensities in the above experiments, the next step in the research program was to establish what the critical maximum light levels were for each species. We have defined critical maximum as the light intensity level above which no further significant increase in shoot length occurs when seedlings are grown under extended daylengths using supplemental light (Arnott and Macey (1984). White spruce, Engelmann spruce, and mountain hemlock were chosen for this experiment at PFRC. Again, a 400-watt lamp was used as the supplemental light source from May 6 - August 16, 1982. The seedlings were grown in an unheated shelterhouse at varying horizontal distances from a HPS lamp so that they received the following light intensities during the extended portion (beyond sunset) of a 19-hour photoperiod regime.

Distance From Light Source		Supplemental Light Intensity
(ft)	(m)	(lux)
4.8	1.45	1600
10.7	3.25	800
18.0	5.45	400
28.7	8.70	200
37.1	11.25	100
-	-	0(control)

Results of this experiment will soon be published (Arnott and Macey 1984) and are summarized here as follows.

As in previous experiments, an extended photoperiod produced large significant increases in seedling shoot length of all three species. The critical maximum light intensities were species-dependent. For white spruce, Engelmann spruce, and mountain hemlock, the figures were 800, 100, and 400 lux, respectively. With light intensities approaching the critical maximum levels as they did in this experiment, there were no significant responses in shoot weight, root weight, or root collar diameter to increased light intensi-



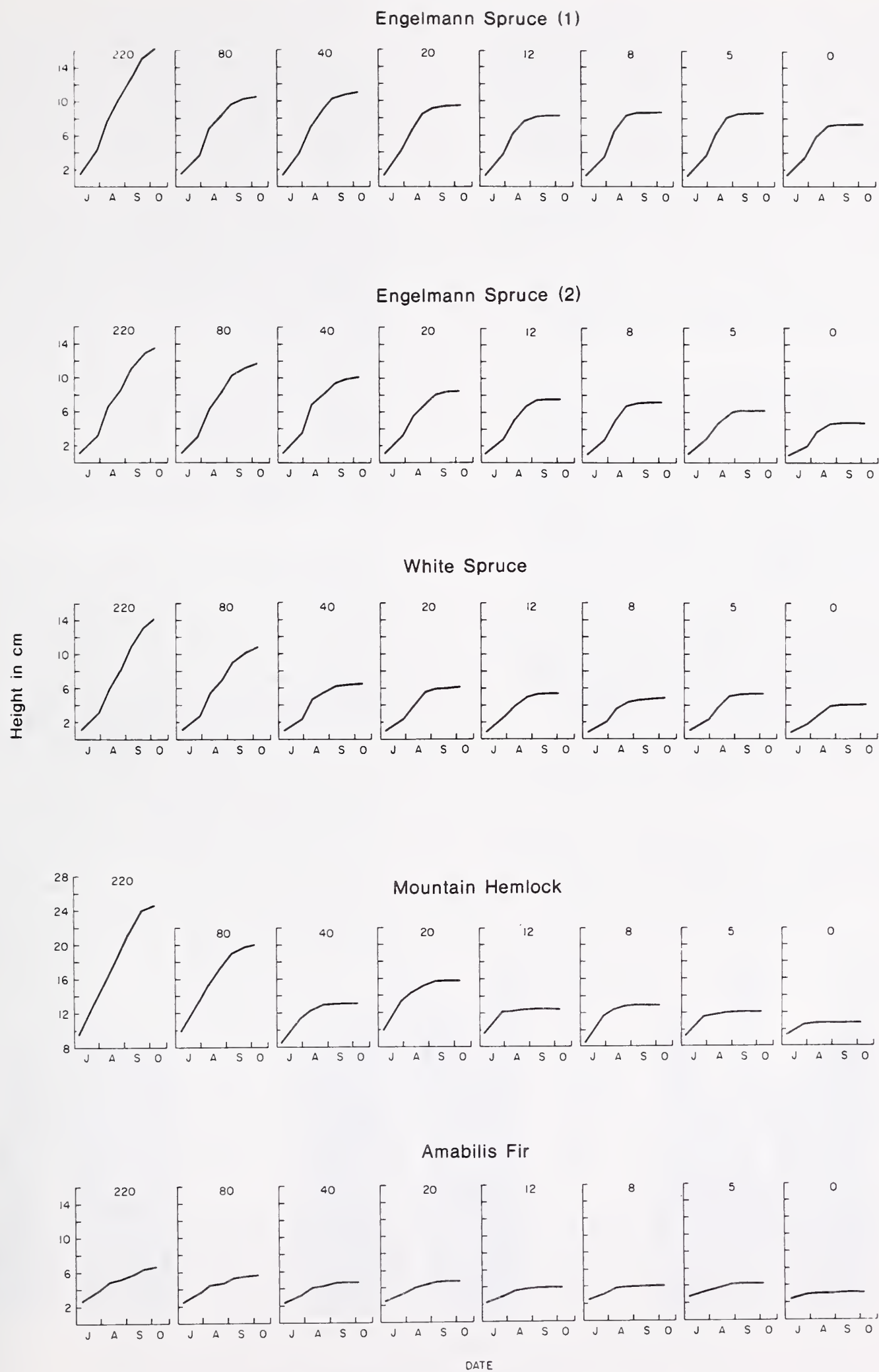


Figure 1.--Height growth of Engelmann spruce, white spruce, mountain hemlock, and amabilis fir seedlings grown in a shadehouse nursery using eight intensities (lux) of supplemental lighting from a HPS lamp (from Arnott 1979).

ties. The only significant increase was in shoot length. The high light intensities did not fully prevent terminal bud formation in white and Engelmann spruce during the extended photoperiod phase of the experiment. The higher light intensities did, however, delay bud formation in white spruce, resulting in significantly greater average shoot lengths for the spruces. In contrast, mountain hemlock was the only species where terminal bud formation was not observed during application of the high light intensity treatments.

#### EFFECT OF EXTENDED DAYLENGTH ON SUBSEQUENT YEAR'S GROWTH

The above seedlings were held over the winter in an unheated shelterhouse for phenological observations of time of bud break and period of shoot growth in the second growing season. The objective was to determine if the use of an extended photoperiod altered the seedlings' growth in the second year. White spruce seedlings that had been grown under an extended photoperiod of high light intensity had completely flushed within 2 weeks, whereas the control seedlings took 5 weeks. However, the flushing sequence of Engelmann spruce and mountain hemlock was not affected by the extended photoperiod. Light intensity of the extended photoperiod used in the nursery had little effect on the length of second-year shoot growth of all three species tested (Arnott and Macey 1984).

#### EFFECTS OF LIGHT FAILURE

Growers using extended photoperiod should also be aware of the consequences of the failure of their lighting systems on tree seedling growth. This factor was investigated in controlled growth rooms and greenhouses at PFRC in 1982.

Seedlings from a north-latitude source of white spruce, and from a high-elevation source of Engelmann spruce and mountain hemlock were sown on March 3, 1982. The spruce were grown in controlled environment chambers under simulated conditions of a 16-hour day (16,340 lux from cool white fluorescent and incandescent lamps) supplemented with an additional 3 hours of low-intensity incandescent light of 200 lux. The mountain hemlock seedlings were grown in the greenhouse where natural daylength was supplemented to a 19-hour photoperiod by incandescent lamps providing 200 lux at seedling level. (There was not enough space available in the growth rooms to accommodate all three species.)

Seedlings of each species were subjected to a simulated failure of the extended photoperiod lighting at 6 and 10 weeks from sowing, i.e., on May 15 and June 15, 1982 for various durations: 0, 1, 3, 5, 7 and 9 nights.

One night and three nights of light failure, respectively, had a significant effect on white spruce and mountain hemlock seedling height at the end of the growing season (fig. 2).

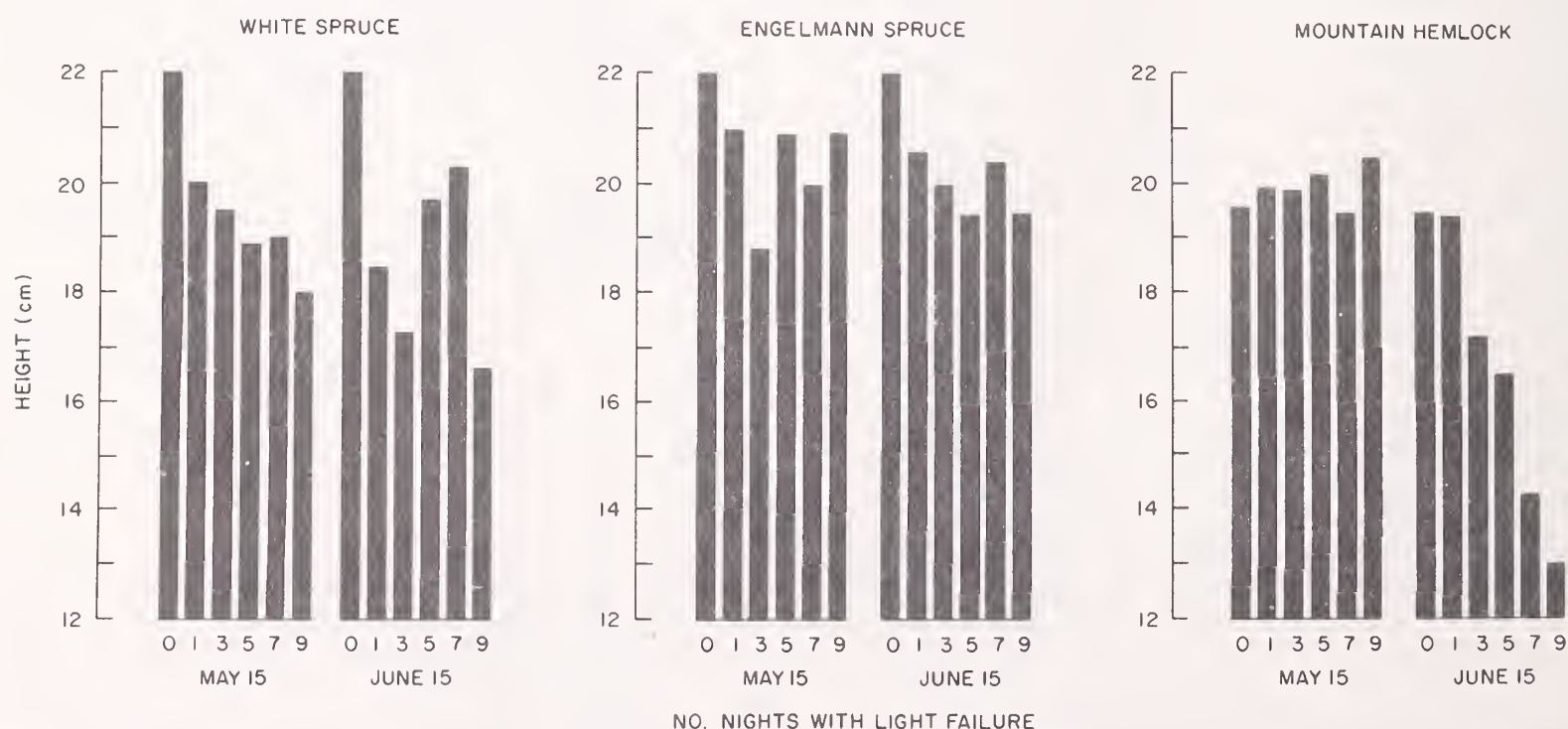


Figure 2.--Effect of 0-9 nights of simulated light failure at two different times in the growing season on white spruce, Engelmann spruce, and mountain hemlock seedlings.



There was a weak negative linear trend of Engelmann spruce seedling height and the numbers of nights with light failure (fig. 2). However, no significant differences were detected between the nights of light failure treatments on Engelmann spruce. White and Engelmann spruce seedlings responded similarly to nights of light failure in May and June. However, time of failure, in terms of seedling age, had a highly significant effect on the response of mountain hemlock seedlings. In May, photoperiod lighting failure had no significant effect on the 6-week-old mountain hemlock seedlings. In June, highly significant differences were detected when 10-week-old seedlings were subjected to the same range of treatments.

The general conclusion from this experiment was that north-latitude and high-altitude ecotypes growing under extended photoperiod are sensitive to any minor failure in the lighting system and that the sensitivity of some seedling species to such failure increases with age.

#### CONCLUSIONS

The above research has played a significant role in supplying B.C. container nursery growers with operational guidelines on the use of photoperiod lighting to grow tree seedlings. This year, artificial lighting systems are being used in 16 nurseries to grow 56 million styroplug seedlings of white spruce, Engelmann spruce, white x Engelmann spruce hybrids, mountain hemlock, amabilis fir, and Interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco). Several light sources are being used, including high pressure sodium (HPS) vapor, tungsten halogen, quartz halogen, and incandescent. Choice of light source is dictated by local nursery preference. There has been no supportive regional research on the halogen light sources although operational experience over the past three years indicates that they work well. The system which I recommend, and which is widely used in B.C., is the HPS lamp that efficiently converts electrical energy to light. Furthermore, the HPS lamp provides a significant amount of light energy in the 600-nanometre range which is within the effective wavelength range for controlling photoperiodism in tree seedlings (Bickford and Dunn 1972).

In B.C., lights are used to extend the photoperiod from sowing date until the seedlings are approaching target heights. They are usually turned off by mid-July to enable the

seedlings to form terminal buds and subsequently develop root and shoot biomass. Nursery growers are cautioned that the use of photoperiod lighting into the latter half of the growing season to favor height growth will have a negative effect on root growth (Arnott 1979) and will predispose the seedling shoots to injury from possible early fall frosts.

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INFLUENCE OF FALL FERTILIZATION AND MOISTURE STRESS ON GROWTH

AND FIELD PERFORMANCE OF CONTAINER-GROWN DOUGLAS-FIR SEEDLINGS

Thomas M. Jopson and Jack L. Paul

**ABSTRACT:** Five fertilizer treatments (+NPK, minus N, minus P, minus K, and tap water) and two wilt treatments (wilt, and non-wilt) were applied to container-grown Douglas-fir seedlings during the fall in the greenhouse. Seedling growth in the nursery was measured. Seedlings were outplanted in mid-winter and growth and performance after planting were evaluated near the beginning and at the end of the growing season. Seedling growth in the nursery and growth and survival after planting were substantially reduced in treatments not receiving nitrogen. Removal of phosphorus or potassium had no discernable effect on growth. The wilting practice was detrimental to seedling growth, both in the nursery and after planting.

#### INTRODUCTION

The literature does not provide a strong basis for choosing one of the many cultural practices used during the hardening-off and dormant periods of seedling growth in the nursery. Most nurserymen use some form of moisture stress coupled with a reduction or temporary removal of all nitrogen from their liquid feed program to begin hardening-off and achieve budset (Hahn 1982). During the dormant period, many nurserymen feed with high phosphorus nutrient solutions, which are thought to enhance root and caliper development (Van Eerden 1974).

Since the goal of nursery cultural programs is the production of seedlings that perform well in the field after outplanting, alternative nursery practices are best evaluated by comparing the field performance of the resulting seedlings. There are few reports in the literature relating specific nursery practices with field performance. This paper investigates the effects of nitrogen, phosphorus, and potassium fertilization and of a wilting practice during these two critical growth periods by relating specific nursery practices to seedling performance in the field after outplanting.

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#### MATERIALS AND METHODS

The experiment described in this paper was conducted at the Cal Forest nursery in Covelo, California, located in Round Valley in northeastern Mendocino County. Round Valley is an interior valley receiving little coastal climatic influence. Summer highs range from 85 to 105 F (30 to 40 C), but nights are generally cool, 50 to 65 F (10 to 20 C). In the fall, the days are warm, but nights are often quite cold (20 F) because of radiation cooling. Winter highs may reach 60 F (15 C), with lows down to 12.

Seedling Douglas-fir were subjected to different cultural treatments and their responses evaluated during the two-part experiment. The nursery phase, during which fertilizer and wilt treatments were applied, began on September 6, 1982, and ended on February 9, 1983. Wilt treatments were applied during the month of September only, while fertilizer treatments were applied throughout the nursery phase. The outplanting phase, during which seedlings were planted in the field (with no further treatments) and were evaluated for growth and survival, began on February 9, 1983.

Five fertilizer treatments were applied during the nursery phase, including complete NPK, minus nitrogen, minus phosphorus, minus potassium, and a tap water control. A wilt treatment and a non-wilt treatment were applied to each of the 5 fertilizer treatments, giving a total of 10 treatments in the experiment. Measurements of seedling growth and nutrient content were made four times: 1) at budset in the nursery; 2) at the time of outplanting; 3) in the spring about 4 months after outplanting; and 4) at the end of the first growing season on November 27, 1983.

#### Nursery Phase

Materials--Douglas-fir seedlings were grown from seed from California seed zone 340-25. The seed was sown in late April into #4 styro-quarter blocks filled with commercially prepared 1:1 peat:vermiculite mix (W.R Grace Forestry Mix). Trees were grown outdoors under a nominal 30 percent shade cloth (to give 70 percent of full sun). Fertilization began in early June with 30:10:10 ppm NPK solution increasing to 100:30:30 NPK by the end of June. In the middle of July, the solution was changed to 100:25:150 NPK and remained at that level until the end of August. Immediately prior to being removed for the experiment, seedlings were leached with tap water applied for 4 hours through sprinklers.



Table 1.--Nutrient solution composition and concentration used for liquid feed fertilizer treatments

Nutrient	Treatment Solutions ( mg/liter )					Nutrient Source
	CON	-N	+NPK	-P	-K	
NO <sub>3</sub> -N	-	-	70	70	70	NH <sub>4</sub> NO <sub>3</sub> , Ca(NO <sub>3</sub> ) <sub>2</sub>
NH <sub>4</sub> -N	-	-	30	30	30	NH <sub>4</sub> NO <sub>3</sub>
P	-	30	30	-	30	H <sub>3</sub> PO <sub>4</sub>
K	-	134	134	134	-	K <sub>2</sub> SO <sub>4</sub>
S	-	54	54	54	40	K <sub>2</sub> SO <sub>4</sub> , MgSO <sub>4</sub>
Ca	-	40	57	57	57	Ca(NO <sub>3</sub> ) <sub>2</sub> , CaCl <sub>2</sub> in <sup>-</sup> -N
Mg	-	30	30	30	30	MgSO <sub>4</sub>
Fe	-	4	4	4	4	330 Fe chelate
Bc	-	.070	all treatments contained the same micronutrient concn. except the control which contained none.			Peters STEM
Cu	-	.15				"
MN	-	.39				"
Mo	-	.0022				"
Zn	-	.21				"

The fertilizer solutions were prepared as needed by mixing the commercial fertilizers as indicated in table 1 with tap water in 70-liter plastic containers.

Methods--Irrigation was accomplished by immersing the blocks in the appropriate solution until the bubbling of air from the media ceased. Wilt treatment trees were stressed to the wilting point before each of the first three irrigations (about 6 days apart). Trees were considered wilted when the terminals were drooping over slightly. Irrigation with nutrient solutions was continued in both non-wilt and wilt treatments until the beginning of the outplanting phase on 2/9/83.

Data collection--Dates and measurements taken are given in table 2.

Table 2.--Experimental measurements taken at different times during the experiment

Type of Measurement	Date <sup>1/</sup>									
	9/1/82		10/23/82		2/9/83		5/26/83		11/27/83	
	A	S	A	S	A	S	A	S	A	S
Stem height	X		X		X		X		X	
Stem caliper	X		X		X		X		X	
Shoot fresh & dry weight		X		X		X		X		X
Root fresh & dry weight		X		X		X		X		X
N content		X		X		X		X		X
P content		X		X		X		X		X
Number of roots emerging								X		X
Root length								X		X

1/ A = All trees measured

S = Sample of trees measured

## Outplanting Phase

The outplanting area was chosen as typical of the many planting sites in the interior Coast Range region of northwestern California. It was on a southeast slope at 2,000 feet (610 meters) on Dingman Ridge just east of Round Valley. Soil type is designated as SITES (depth 2-3 feet [60-90 cm]) on the California soil-vegetation map (43a-3). The surface soil is described as a moderately acid loam with fair timber growing capability. In January, the outplanting area was ripped to a depth of approximately 18 inches (45 cm) with a three-bottom Howard V-Chisel behind a MF 238 tractor. The area was then disced twice. A light cover of grass, plus a heavy cover of star thistle in plot #3, developed in the outplanting area despite the discing.

Data collection--Dates and measurements taken are given in table 2.

Tissue analysis methods--Shoot nitrogen was determined by micro-Kjeldahl procedure. Shoot phosphorus was determined by a molybdate blue procedure.

## RESULTS AND DISCUSSION

The presentation of results is divided into two sections: the first on the nursery phase, the second on the outplanting phase. Reference is made in the text to the following time periods:

### Nursery phase

9/6 -10/23 -hardening-off period  
10/23- 2/9 -dormant period

### Outplanting phase

2/9 - 5/26 --spring period  
5/26-11/27 --summer/fall period

### Nursery Phase

Treatments resulted in differences in seedling appearance, mortality, time of budset, and seedling growth. Differences in appearance were apparent within 3 weeks after the start of treatments on 9/6 with -N and control seedlings beginning to show chlorosis. This chlorotic condition persisted throughout the nursery phase, although it did not visibly worsen after the first month. During the dormant period, some seedling mortality occurred; wilted trees, particularly those not receiving nitrogen, showed a greater mortality rate in the nursery.

As indicated by the percent of seedlings with terminal buds on 10/23, there were differences in the average time of budset. The control and minus N seedlings set buds more rapidly on the average than the nitrogen-fertilized seedlings. Wilting had the expected effect of promoting more rapid budset in seedlings supplied with nitrogen, but seemed to slow budset in -N and control seedlings. Despite the differences noted above, all seedlings did eventually set a terminal bud, and no frost damage was observed.

Table 3.--Seedling stem height during and at the end of the nursery phase

Sample Date	Period	Height in centimeters(cm)										LSD .05	seedlings per treat.
		Treatments											
		CON	Non-wilt -N	+NPK	-P	-K	CON	-N	Wilt +NPK	-P	-K		
9/6	Begin	11.0	11.0	10.8	11.2	11.0	10.5	10.6	10.4	10.6	10.8	0.7	100
10/23	hrdg off	13.5	13.2	14.4	15.0	15.0	12.4	13.0	13.0	13.2	13.7	0.9	100
2/9	dormant	13.5	13.0	14.5	15.0	15.3	12.2	13.0	13.3	13.3	14.0	0.9	100

Table 4.--Seedling stem caliper measured 0.5 cm above the cotyledonary scar during and at the end of the nursery phase

Sample Date	Period	Caliper in millimeters(mm)										LSD .05	seedlings per treat.
		Treatments											
		CON	-N	Non-wilt +NPK	-P	-K	CON	-N	Wilt +NPK	-P	-K		
9/6	Begin	2.0	2.0	2.0	2.0	2.0	2.0	1.9	2.0	1.9	2.0	.07	100
10/23	hrdg off	2.5	2.5	2.9	2.9	3.0	2.2	2.4	2.6	2.5	2.6	.10	100
2/9	Dormant	2.5	2.5	3.1	3.0	3.1	2.2	2.4	2.7	2.7	2.7	.13	100

Height and Caliper--Height and caliper measurements are given in table 3 and table 4.

Dry Weight (table 5)--Shoot dry weight increases during the nursery phase ranged from 0.3 grams (wilt-control) to 0.8 grams (non-wilt+NPK), with 2/3 of the gain occurring during the hardening-off period, and 1/3 during the dormancy period. Root dry weight gains were just about evenly distributed between the hardening off and the dormant period, with total gains ranging from 0.3 grams (wilt-control) to 0.75 grams (non-wilt-K). Nitrogen fertilization did not increase root dry weight over controls during the hardening-off period, but did significantly increase root dry-weight during the dormant period. Compared to the NPK treatments, the -P and -K treatments consistently produced greater root weights in the wilted treatments, but produced the same, or lower weights in the non-wilted treatments. None of these effects was statistically significant, however. During the hardening-off period, wilted seedlings produced only about 1/2 as much root dry weight as non-wilted seedlings, but during the dormant period, average root dry weight production was nearly the same. Thus, by the time of outplanting, roots were growing at the same rate in both groups.

Shoot Nitrogen (table 6)--Seedlings deprived of nitrogen became chlorotic within 4 weeks of the beginning of the treatments, and still appeared chlorotic when outplanted. Nitrogen fertilization resulted in significantly higher shoot nitrogen percent at the end of the nursery phase when compared to -N and controls.

Shoot Phosphorus (table 6)--The phosphorus content was high at the end of the budset period, but declined during the dormant period. However, phosphorus levels in the minus P treatments remained within the range found in seedling Douglas-fir (0.16 percent to 0.30 percent)(van den Driessche 1969).

Table 5.--Average shoot and root dry weight of seedlings sampled during the nursery phase

Shoots (grams)													
Sample Date	Period	Treatments										LSD .05	Seedlings per treat.
		CON	Non-wilt -N	+NPK	-P	-K	CON	Wilt -N	+NPK	-P	-K		
9/6	Begin	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40		
10/23	Hrdg-off	0.80	0.90	0.89	1.01	1.04	0.79	0.73	0.79	0.80	0.75	0.21	10
2/9	Dormant	1.12	0.90	1.33	1.39	1.28	0.89	0.90	1.03	1.11	1.19	0.30	10

Roots (grams)													
Sample Date	Period	Treatments										LSD .05	Seedlings per treat
		CON	Non-wilt -N	+NPK	-P	-K	CON	Wilt -N	+NPK	-P	-K		
9/6	Begin	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20		
11/23	Hrdg-off	0.43	0.45	0.42	0.46	0.48	0.39	0.33	0.37	0.34	0.38	0.09	10
2/9	Dormant	0.72	0.61	0.96	0.91	0.98	0.57	0.60	0.82	0.90	0.89	0.23	10

Table 6.--Average shoot (needles and stem) tissue nitrogen percent and phosphorus percent of samples taken during the nursery phase

Sample Date	Period	% NITROGEN										LSD .05	Seedlings per treat.
		Treatment											
		Non-wilt					Wilt						
		CON	-N	+NPK	-P	-K	CON	-N	+NPK	-P	-K		
9/6	Begin	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6		1/
10/23	Hrdg-off	0.86	0.86	1.87	1.77	1.67	0.80	0.92	1.50	1.67	2.02	.39	4
2/9	Dormant	0.90	0.90	1.67	1.70	1.67	0.97	0.80	1.67	1.57	1.65	.20	4

		% PHOSPHORUS											
Sample Date	Period	Treatment										LSD .05	Seedlings per treat.
		CON	Non-wilt -N	+NPK	-P	-K	CON	Wilt -N	+NPK	-P	-K		
9/6	Begin												1/
10/23	Hrdg-off			0.45	0.36				0.37	0.31		.07	4
2/9	Dormant			0.24	0.18				0.20	0.21		.05	4

1/ Value derived from as sample of ten trees from the same population as the experimental trees.

#### Outplanting Phase

At the time of the spring evaluation (May 26) seedlings from most of the treatments appeared to be in excellent condition. However, seedlings from both minus N treatments and the wilt control seedlings appeared to be more spindly and had sparser foliage than the others. Seedling survival at this time was excellent (table 11), with all mortality occurring in the wilted seedlings. Growth and survival were also recorded at the end of the growing season on November 27(summer/fall period), when seedlings were dormant and after the fall rains. At that time, large differences between treatments had become apparent.

New Shoot Growth and Caliper--New shoot growth and caliper measurements are given in table 7.

Dry Weight (table 8 and figure 1)--Shoot and root dry weight increases were markedly influenced by nitrogen fertilization in the nursery. Nitrogen-fertilized seedlings accumulated twice the dry weight of the nitrogen-deprived seedlings during the outplanting phase. Shoot dry weight gain was the same in the spring and summer/fall periods,



Table 7.--New shoot growth and stem caliper of seedlings after outplanting

NEW SHOOT GROWTH (cm)													
Sample Date	Period	Treatment										LSD .05	Seedlings per treat.
		CON	-N	Non-wilt +NPK	-P	-K	CON	-N	Wilt +NPK	-P	-K		
5/26	Spring	1.56	2.27	4.22	3.66	3.68	1.36	2.14	3.26	3.07	3.55	1.39	9
11/27	Sum/fall	3.64	2.87	5.20	4.26	5.33	2.75	*	5.91	4.64	4.85	1.49	9

CALIPER (mm)													
Sample Date	Period	Treatment										LSD .05	Seedlings per treat.
		CON	-N	Non-wilt +NPK	-P	-K	CON	-N	Wilt +NPK	-P	-K		
5/26	Spring	3.2	3.3	4.2	4.4	4.1	2.9	3.0	3.6	4.0	3.5	0.8	9
11/27	Sum/fall	4.0	4.0	5.5	4.8	5.4	3.2	*	4.6	5.0	5.1	0.3	8

\*too few survivors to obtain an adequate sample

while 1/3 of the root dry weight gain was in the spring and 2/3 in the summer/fall. The wilt treatment had very little effect on the accumulation of dry weight during the outplanting phase, but weight reductions from the nursery phase were not regained.

Roots growing from the rootball (table 9)--The influence of fertilization on root growth in the field was apparent in the count of roots emerging from the rootball and in average length of emerged roots. The data show that nitrogen fertilization increases both the number of roots emerging and the average length. Wilting had a significant effect only in the +NPK treatment

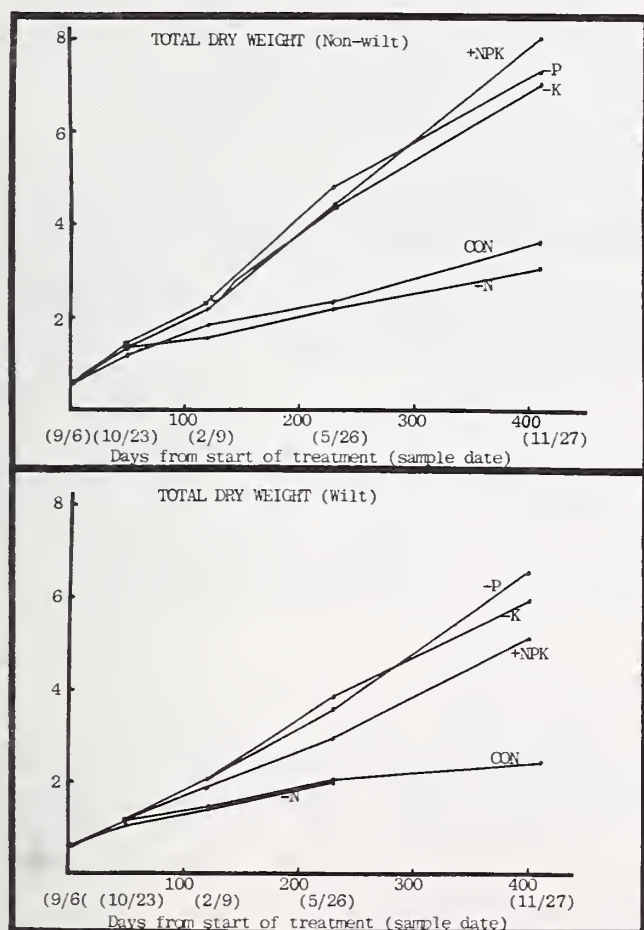


Figure 1.--Total seedling dry weight (root plus shoot) for each non-wilted fertilizer treatment (top) and each wilted fertilizer treatment at the beginning of the experiment and at the end of each experimental period

Table 8.--Average shoot and root dry weight of seedlings dug after the spring growth period and at the end of the first growing season after planting

Shoot (grams)													
Sample Date	Period	Treatment										LSD .05	Seedlings per treat.
		CON	Non-wilt -N	+NPK	-P	-K	CON	Wilt -N	+NPK	-P	-K		
5/26	Spring	1.20	1.28	2.39	2.63	2.49	1.11	1.07	1.54	1.76	2.00	.44	9
11/27	Sum/Fall	1.55	1.33	3.50	3.44	3.08	0.95	*	2.28	2.53	2.96	.98	8

Root (grams)													
Sample Date	Period	Treatment										LSD .05	Seedlings per treat.
		CON	Non-wilt -N	+NPK	-P	-K	CON	Wilt -N	+NPK	-P	-K		
5/26	Spring	1.12	0.98	2.06	2.18	1.97	0.90	0.90	1.33	1.54	1.55	.46	9
22/27	Sum/Fall	2.10	1.73	4.53	3.91	4.02	1.49	*	2.84	3.44	3.57	1.17	8

\*too few survivors to obtain an adequate sample

where it resulted in a significant reduction in the number of roots emerging from the plug.

Tissue analysis (table 10)--Shoot nitrogen percent was more variable after outplanting than in the nursery. Seedlings from nitrogen-fertilized treatments generally had a higher nitrogen content than seedlings deprived of nitrogen, but differences were not significant in most cases. Observed nitrogen levels were similar to other observations of Douglas-fir in the field (Lavender and Carmichael 1966; Smith and others, 1981). Shoot phosphorus declined after outplanting; the final levels were slightly lower than observed elsewhere (Lavender and Carmichael 1966)

Table 9.--New root growth from the root ball into the soil after outplanting

Number of New Roots Per Seedling													
Sample Date	Period	Treatment										LSD .05	Seedlings per treat.
		CON	Non-wilt		Wilt			CON	Non-wilt		Wilt		
			-N	+NPK	-P	-K		-N	+NPK	-P	-K		
5/26	Spring	34	20	65	41	48	20	22	35	41	59	18	9
11/27	Sum/Fall	37	26	64	45	52	31	*	36	45	53	19	8

Average Length of New Roots (cm)													
Sample Date	Period	Treatment										LSD .05	Seedlings per treat.
		CON	Non-wilt		Wilt			CON	Non-wilt		Wilt		
			-N	+NPK	-P	-K		-N	+NPK	-P	-K		
5/26	Spring	1.9	2.9	3.5	2.9	2.9	1.9	2.1	2.1	3.2	3.2	1.2	9
11/27	Sum/Fall	3.9	5.2	6.9	7.5	6.8	4.0	*	4.2	6.5	5.5	2.0	8

Average Root Extension (Length x number) (cm)													
Sample Date	Period	Treatment										LSD .05	Seedlings per treat.
		CON	Non-wilt		Wilt			CON	Non-wilt		Wilt		
			-N	+NPK	-P	-K		-N	+NPK	-P	-K		
5/26	Spring	76	58	225	184	154	50	55	107	157	196	87	9
11/27	Sum/Fall	189	136	465	362	372	127	*	188	311	375	171	8

\*too few survivors to obtain an adequate sample



Table 10.--Shoot (needles and stem) tissue nitrogen percent and phosphorus percent in seedlings dug during and after the first growing season after planting

Nitrogen (%)													
Sample Date	Period	Treatment										LSD .05	Seedlings per treat.
		CON	Non-wilt			Wilt							
		-N	+NPK	-P	-K	CON	-N	+NPK	-P	-K			
5/26	Spring	0.75	0.95	1.15	1.27	1.20	1.12	1.00	1.27	1.02	1.12	.37	4
11/27	Sum/Fall	1.17	0.97	1.50	1.07	1.20	0.96	1.00	1.22	1.22	1.55	.33	4

Phosphorus (%)													
Sample Date	Period	Treatment										LSD .05	Seedlings per treat.
		CON	Non-wilt			Wilt							
		-N	+NPK	-P	-K	CON	-N	+NPK	-P	-K			
5/26	Spring		0.14	0.13				0.15	0.13		.02	4	
11/27	Sum/Fall		0.16	0.13				0.12	0.11		.02	4	

Survival (table 11)--Seedling survival after outplanting was improved by nitrogen fertilization in the nursery. Wilting reduced survival in all treatments except +NPK.

## DISCUSSION

Growth and survival after outplanting were clearly enhanced by nitrogen fertilization during the hardening-off and dormant periods in the nursery. The correlations between root and shoot dry weights at the end of the nursery phase and root and shoot dry weight at end of both the spring and summer/fall periods in the field demonstrate that good seedling growth in the field is strongly related to cultural practices which enhance growth in the nursery (table 12). Good correlations between survival and root and shoot dry weights at the end of the nursery phase indicate a relationship between seedling growth, as enhanced by nitrogen fertilization, and seedling survival (table 12).

Utilizing the relatively large supply of nitrogen in the shoot, and perhaps the roots, nitrogen-fertilized seedlings were able to attain shoot growth rates 10 times greater and root growth rates almost 3 times greater than nitrogen-deprived seedlings during the spring period of the outplanting phase (figure 2).

The root dry weight increases derived from increases in both the number and average length of new roots and resulted in significantly greater total average root extension (table 9). Nitrogen-fertilized seedlings had much greater root contact with the soil, and hence greater access to soil water and nutrients. Heiner and Lavender (1972) obtained a correlation between early root growth and Douglas-fir seedling survival. They also found a correlation between early budburst in the spring and survival, and suggested that early budburst is indicative of early root growth. In the current study, early root and shoot growth, as indicated by growth rates during the spring period, were well correlated with survival (table 12), while correlation between growth rate and survival for the other experimental period is relatively poor.

Table 11.--Percentage of seedling surviving in the spring and at the end of the first growing season after outplanting

Sample Date	Period	Percent(%)										Seedlings per treat.
		Non-wilt					Wilt					
		CON	-N	+NPK	-P	-K	CON	-N	+NPK	-P	-K	
5/8	Spring	100	100	100	100	100	96	98	95	100	98	56
11/27	Sum/Fall	20	11	31	47	47	13	5	29	27	24	47

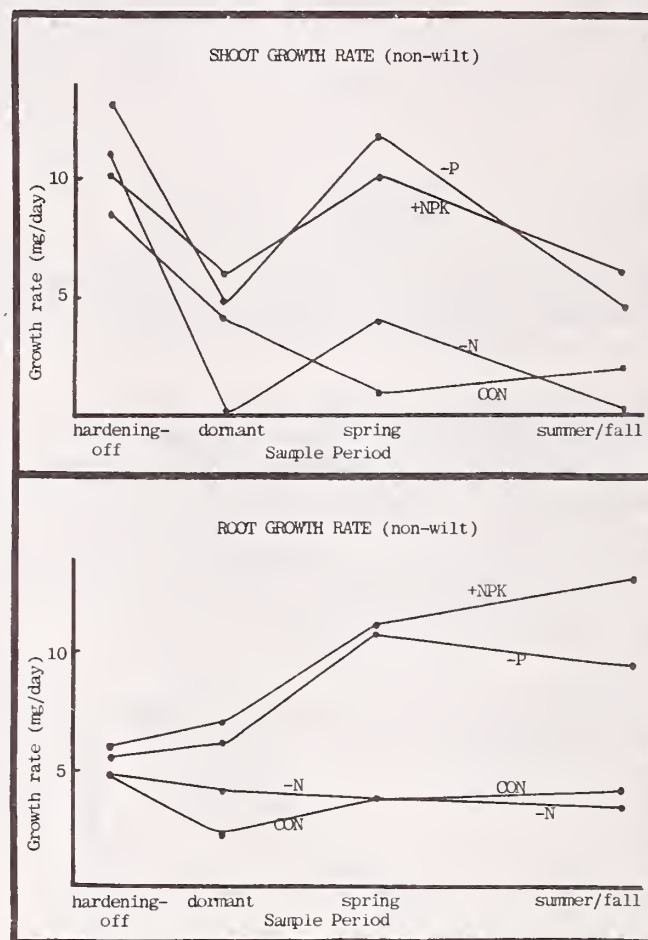


Figure 2.--Average root and shoot dry weight growth rates of non-wilted seedlings during selected experimental periods

Table 12.--Linear regression analysis of treatment means

"X" Means	"Y" Means	Regression equation	R <sup>2</sup>
2/9 shoot dry wgt, grams	5/26 shoot dry wgt	Y = 3.0X - 1.7	.87
"	11/27 " " "	Y = 4.6x - 2.9	.86
2/9 root dry wgt, grams	5/26 root dry wgt	Y = 2.9X - 0.8	.85
"	11/27 " " "	Y = 6.9X - 2.5	.95
2/9 shoot dry weight	11/27 survival(%)	Y = 67X - 50	.77
" root " "	"	Y = 78X - 36	.75
shoot growth rate (mg/day)	11/27 survival(%)	Y = .40X + 12	.27
Dormant period	"	Y = .31X + 7	.78
Spring period	"	Y = .52X - 1	.51
root growth rate (mg/day)	"	Y = .40x + 2	.79
Dormant period	"		
Spring period	"		

These results emphasize the importance of early, vigorous seedling growth after outplanting, a characteristic which is greatly enhanced by nitrogen fertilization during the hardening-off and dormant periods in the nursery.

The use of high phosphorus levels to improve root development in the nursery during the dormant period as recommended in many cultural programs (Brix and van den Dreissche 1974, van Eerden 1974) is unnecessary. Removal of phosphorus from the nutrient solution did not reduce growth of roots or shoots. Nitrogen was the primary element controlling root growth rates in the current experiment. Philipson and Coutts (1977) obtained the same result for root growth in Sitka spruce using split-root techniques. They found that phosphorus played only a secondary role.

Application of moisture stress up to -15 bars late in the growing season had the anticipated but unimportant effect of increasing the rate of budset, but was detrimental to growth and survival in the field. The major effect of wilting was reduction of spring growth rates, particularly spring root growth rates. Non-wilted seedlings showed substantial growth rate increases during the same time period (figure 3). No explanation of this effect is suggested by the data collected in this experiment.

## CONCLUSIONS

Nursery cultural practices late in the growing season have a strong and persistent influence on seedling performance after outplanting. Nitrogen fertilization during the hardening-off and dormant periods was a beneficial practice. It consistently resulted in increased seedling growth, and hence increased seedling size, throughout the experiment. Nitrogen effects were most significant during the spring growth period immediately after outplanting, when large increases in growth rate were observed in nitrogen-fertilized seedlings. The results did not support the practice of supplying phosphorus during the dormant period in the nursery. Phosphorus provided no additional benefit beyond that attributable to nitrogen. Moisture stress to the wilting point during the hardening-off period in September proved detrimental to seedling performance in the field.

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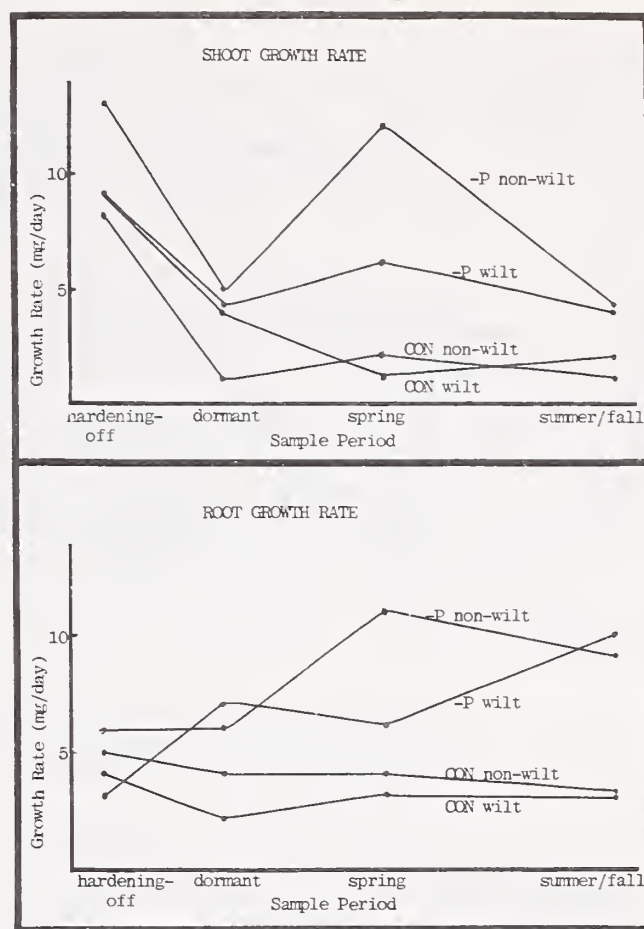


Figure 3.--Average root and shoot dry weight growth rates of wilted and non-wilted seedlings for minus-P and Control fertilizer treatments



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FOREST SERVICE  
EQUIPMENT DEVELOPMENT REFORESTATION PROGRAM

James Lott

ABSTRACT: This paper briefly covers current projects in the reforestation program at Missoula Equipment Development Center (MEDC) and San Dimas Equipment Development Center (SDEDC) which includes; the Cull Seedling Grinder, Nursery Equipment Investigation, Precision Seeder, Spot Site Preparation Equipment, Wildland Cone Harvesting Equipment, Intermittent Tree Planters, Low-Energy Cone-Drying Kiln, and Seedbed Thinning Equipment.

#### INTRODUCTION

MEDC is one of two Development Centers in the Forest Service. The following is a brief overview of current reforestation projects at MEDC and SDEDC.

#### CULL SEEDLING GRINDER

Forest nurseries have the problem of disposing of cull seedlings. Most current disposal methods are expensive because of handling, and are wasteful because the seedlings' organic matter is not recycled. To remedy the situation, MEDC was asked to make available a grinding system that could efficiently reduce wet, muddy cull seedlings to segments less than 1-inch (2.54-cm) long. In 1980, a market search was conducted to determine what equipment is available.

In 1981, testing was begun by experimenting with a medium-size (35-horsepower) (26 kw) grinder. It soon became apparent that more horsepower was needed to properly prepare the seedlings for the nurserybed. In 1982, modifications were made to the grinding system to improve the grinding action. The testing of a larger (120-horsepower) (90 kw) grinder was begun at a second Forest Service nursery. Testing and additional modifications were made in 1982. All testing was completed in 1983.

In 1984, the results of the 3-year testing program will be written up for an article in Tree Planters' Notes, and also presented at selected nursery association meetings. It appears that when all modifications are incorporated into the seedling grinding system, nursery managers will have the

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techniques needed to use cull material to upgrade economically the organic content of their nursery soils. This will save both the cost of buying soil amendments and cull seedling disposal costs.

#### NURSERY EQUIPMENT INVESTIGATION

Under this project MEDC will investigate the reported need to improve equipment for three nursery operations:

(1) Seedling Lifter - Although several mechanical seedling lifters are commercially available, most nursery managers still prefer to lift manually. For various reasons, they do not trust their crop to the available machines. But, they do recognize that mechanical lifting must be improved and implemented.

(2) Root Pruner - Vertical and horizontal pruning of seedling roots in the nurserybed has been done to some degree by most nursery managers for many years. Recent experience suggests that the practice should be expanded, but more control and precision is sought. Nursery managers want improved root-pruning equipment that will give them the quality results they need.

(3) Transplanter - Field foresters are finding that transplanted seedlings can often survive on harsh sites where regular nursery stock cannot. Transplanting seedlings at the nursery can improve the root-shoot ratio, size, and vigor of a seedling. Northwest nursery managers have recently stated that old transplant equipment currently used is not suitable because of changing requirements and costs. New, improved nursery transplant equipment is needed.

#### PRECISION SEEDER

As forest nursery personnel attempt to produce large and more vigorous and uniform seedlings, more precision and uniformity is required in every phase of their operation. Perhaps the step that requires the most precision is sowing the seed. Uniformly spaced seed in the nurserybed helps determine the quality of subsequent cultural practices. A recent survey of northwest forest nurseries revealed that the need for a precision seeder is high on the equipment improvement list.

In 1983, the MEDC was funded to investigate the requirements for a precision seeder and to determine how current seeders rank in regard to those requirements.



## SPOT SITE PREPARATION EQUIPMENT

In 1976, MEDC conducted a survey to identify Timber Management equipment needs. The lack of equipment for removing competing vegetation from selected spots on steep slopes ranked as one of the top five problems. Accomplishing spot site preparation on steep slopes has become a serious problem because aerial logging methods have made it more feasible to work on such slopes. Also, land managers are increasingly concerned about compaction caused by the heavy ground equipment used for site preparation. The goal is to make available the equipment Timber Management personnel need to do spot site preparation on steep slopes.

In 1980, a selected group of Forest Service Timber Management personnel met to define the problem and set development criteria. MEDC was assigned the task of improving or developing spot site preparation equipment in five categories: (1) cable yarder operated, (2) dozer mounted, (3) handtools, (4) thermal, and (5) chemical. A market and literature search was conducted to determine the availability of equipment that could be used in the five categories; typical problem areas were visited to verify development criteria. To begin the development effort, a contract was awarded for the construction of a lightweight, truck-mounted cable yarder.

In 1981, the yarder was delivered and two cable-operated scarification implements were built and tested. Also, three dozer-mounted implements were designed and tested. In 1982 and 1983, two additional cable-operated implements were designed, built, and testing was begun. Site preparation handtools were sent to six Regions for testing. Also, front- and rear-mounted scalpels for crawler tractors were built and tested.

In 1984 final work on cable-operated implements will be done. After testing and final modification, drawings and specifications for the construction of cable-operated implements will be completed.

## WILDLAND CONE HARVESTING EQUIPMENT

To meet expanding reforestation programs, new equipment and techniques are needed. One of the greatest needs is to provide seed that is adapted to the sites to be reforested. To provide the greatest compatibility between seed stock and site conditions, harvesting cones in wildlands is often the only alternative. Rough terrain, thick underbrush, steep slopes, and the widely dispersed and hard-to-reach nature of the cone crop make wildland cone harvesting difficult. The goal is to develop safe, efficient methods of harvesting cones in wildlands and report these methods to field reforestation personnel.

MEDC personnel met with an ad hoc committee representing reforestation experts from various Forest Service units. The committee laid out the project goals and prepared a development schedule. The first major effort in the project was to mount a tree shaker on a crawler tractor. The unit was successfully tested on the Winema National Forest, Oregon, in 1981 and 1982. This unit is designed to work in roadless areas. A shaker with a 30-foot (9-m) telescoping boom for truck-mounted, roadside shaking, was also fabricated and tested in 1982.

The testing indicated that a truck-mounted shaker with a long reach can produce, quickly and efficiently, many bushels of cones along the roadside. In 1983, a progress report was written to describe the work done to date. Drawings were prepared for the crawler-tractor-mounted shaker. A totally new slip-on truck-mounted shaker was designed, and will be fabricated and tested before the end of 1984.

## INTERMITTENT TREE PLANTERS

Successful tree planting on National Forests, through the use of commercially produced intermittent containerized and bare-root planting machines, is the objective of this project. More uniform, higher quality, and lower cost planting are possible advantages of intermittent tree-planting machines. Also, compared to continuous-furrow tree-planting machines, intermittent ones generally cause less ground disturbance (resulting in lower soil erosion potential), can require lower energy inputs, require less site preparation (resulting in further energy conservation), and provide a more natural regeneration appearance.

In a market survey, three recently developed intermittent tree planters were found that showed promise enough to warrant field evaluation. They were the Marden Spot Planter model 100, the Timberland single-row, self-powered planter, and the Timberland two-row "HODAG." The model 100 was field evaluated in 1981 and in 1982, SDEDC distributed a Project Record on the evaluation. The tests were based on a "Performance Criteria for Intermittent Tree Planter," developed by San Dimas in cooperation with the Southeastern Area, State and Private Forestry, and approved by the Forest Regeneration Committee, which is chaired by the Assistant Director of Silviculture, Timber Management Staff, Washington Office. The Marden model 100 met most of the criteria.

Following improvements made by the manufacturer to overcome deficiencies, the model 100 was reevaluated in 1982. Also in 1982, both of the Timberland machines were field evaluated and reports on the evaluations were completed. In 1983, the Timberland two-row HODAG and a Marden model 200 tree planter were field evaluated. The model 200 is similar to the 100 but has a self-contained power system.



Based on preliminary information, the Forest Service to date has purchased two HODAG's and three model 100's. Also under this project, SDEDC continues to support the North Carolina State University intermittent tree-planter development program.

#### LOW-ENERGY CONE-DRYING KILN

Several years ago, MEDC personnel conducted an investigation of nursery equipment needs for processing small seedlots. One of the problems was the lack of an energy-efficient, versatile, cone-drying kiln. Because most nurseries were built when energy was cheap and seedlot size was large, oil- or gas-fired drying kilns were built for large-scale drying. In recent years, the trend has been to smaller seedlots, and fuel costs have soared. The old kilns are expensive to operate and inefficient. The goal is to make available a low-energy kiln to dry cones for small seedlots.

MEDC worked with the National Tree Seed Laboratory at Macon, Georgia, to determine the exact costs involved in drying cones at more than 20 seed extractories throughout the country. The survey has been completed and data analyzed. The results show that no one kiln design can meet the requirements of all U.S. seed processors. Instead, what is needed are design criteria for building a kiln that will meet requirements based on both tree species and meteorological conditions at each particular site.

A report will be written to complete the project. The document will serve as a guide to those designing and fabricating cone-drying kilns. By using the information, the builder can incorporate state-of-the-art data to minimize construction costs and, in many instances, substantially reduce operating expenses.

#### SEEDBED THINNING EQUIPMENT

Field personnel involved in reforestation work are asking for larger diameter tree seedlings with better developed root systems. This requires less dense growing conditions in the seedbed. Incorrect germination data or higher-than-expected survival, can cause seedling density to be too high. By thinning, density is controlled and uniform spacing is achieved. But most thinning is done by hand, which is expensive. The goal is to make available to nursery managers equipment that will enable them to thin seedbeds effectively and economically.

MEDC engineers consulted nursery managers to determine requirements for seedbed thinning equipment. A market search revealed several commercially available thinners that potentially could be modified to thin seedling beds. A

commercially available beet thinner was purchased, and tested in 1980. Testing and additional modifications were made in 1981. The results showed that the tractor-mounted thinner can substantially reduce thinning costs. However, it cannot be used under all conditions or on all tree species.

While testing the mechanical thinner, nursery managers suggested that a hand-operated thinner be tested. A prototype was fabricated and testing began. Testing and modification of both systems continued into 1982. Because the hand-operated thinner performed so well, Forest Service nursery managers recommended that no further work be done on the mechanical thinner. Thus, MEDC attention was focused on the hand thinner. A production study was conducted at a Forest Service nursery that showed the hand-operated thinner cut costs (as compared to hand thinning) by 8 to 1.

Ten improved hand-operated thinners were built at MEDC in 1983. They were sent to Forest Service nurseries for summer work. This implementation effort and the preparation of construction drawings and specifications will complete the project.

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CONTRACT GRADING

Richard H. Thatcher

ABSTRACT: Contract grading and counting of over four million seedlings in 10.5 working days was accomplished in conjunction with contract lifting. Daily production rates exceeded nursery employee rates. Percentages of bad trees on grading belts and good trees thrown away were lower than nursery employee rates. The cost was \$0.02/M higher than nursery employee rates.

## INTRODUCTION

Contract grading had been done at Lucky Peak Nursery during the fall of 1981 and 1982. These contracts were for approximately 1MM seedlings each year, after lifting was completed. This was done to work out potential problems in the grading contract without having to worry about field/shed coordination. In our contract, only grading was contracted, all support people were nursery employees. As a result of the experience and confidence gained during the two fall operations, we decided to contract both lifting and grading for the peak work season in the spring of 1984.

Appendix I shows the data for three seasons of contract grading and equivalent Force Account (nursery employee) grading.

Appendix II shows the schedule of items and specifications used in our contract. As with any contract, the success is partly determined by the commitment and quality of the contract inspectors and the contracting officers. We had good people in these positions in the field and shed.

## OBSERVATIONS

1. Gross production for the contract graders was higher than Force Account crews.
2. Bad seedlings on the belt were less than or equal to those of Force Account crews.
3. Good seedlings thrown away were less than for Force Account crews.

Paper presented at combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Coeur d'Alene, ID, August 14-16, 1984.

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4. Force Account grading would have been \$0.02/M cheaper than contracting.

5. To Force Account-grade the volume contract-graded in FY84 would have required an additional 2 days (.55 person years).

6. Of the seedlings not meeting specifications on the belt, 21.6 percent was due to improper count.

## DISCUSSION

1. Contract grading is a viable option. Our experience over three seasons shows an increase in daily production/grader each year. The first two years were with one contractor, and FY84 with another. We don't feel that we have peaked as far as daily production/grader. Just a small increase in the average production would result in a cheaper cost/M by contracting.

2. The average variation in bad seedlings on the four belts ranged from 6.48 to 8.3 percent. This is a reflection on uniformity of inspectors and graders. Inspectors stayed on the same belt for the entire season. This was done to maintain consistency in interpretation of specifications.

3. The incentive bonus for grading above a certain number of seedlings cost an additional \$151. The contract payment is set up so that 91 percent or better quality of graded seedlings resulted in 100 percent pay.

4. For units operating with a personnel ceiling, contracting can be very beneficial. We saved over 2 person years in processing 4MM seedlings.

5. Had we Force Account graded, we would have had to stop lifting for a few days until room could be made in our coolers. The shed would not have been able to keep up with the field operation. This would have a detrimental effect on seedling dormancy.

6. There is a need to look at our minimum daily production rates to recognize problems with difficult grading species.

7. A positive and cooperative working relationship with the contractor and the contractor's foremen is essential.

## CONCLUSIONS

We will continue to try contracting our lifting and grading as long as the cost is equal-or-less than what nursery employees can do, quality of grading is acceptable, and current lifting and grading procedures stay the same.



APPENDIX I

Table I

		Day of Work											Total or Weighted Average
Description	FY	1	2	3	4	5	6	7	8	9	10	10.5	
Contract Min. Production (M)	82-84	250	288	336	350	350	350	350	350	350	350	175	1275M 1114M 4288M 3633M
Premium Pay Volume (M)	83-84	276	321	371	391	391	391	391	391	391	391	195	
Gross Production (M)	82	276	305	359	334								
48 Graders	83	450	386	277									
	84	303	285	317	294	436	402	476	435	581	480	277	
*Force Account	*FA-83	258	321	371	304	371	357	484	405	280	318	164	
Gross Prod./grader/shift (M)	82	5.7	6.3	7.5	7.0								6.9M
	83	9.4	8.0	5.8									8.1M
	84	6.3	5.9	6.6	6.1	9.1	8.4	9.9	9.1	12.2	10.0	11.5	8.5M
	FA-83	5.4	6.7	7.7	6.3	7.7	7.4	10.1	8.4	5.8	6.6	6.8	7.2M
Percent Bad Seedlings on Belt	82	8.03	9.31	10.86	12.98								10.53
	83	11.16	10.29	5.67									9.08
	84	6.69	8.44	8.30	7.51	8.10	7.80	7.39	6.63	7.37	7.21	6.97	8.08
	FA-82	12.86	11.80	10.41	7.87								10.82
Percent Good Seedlings on Floor	82	9.74	7.43	5.76	7.61								7.39
	83	7.98	5.99	5.28									6.22
	84	3.15	3.87	3.47	4.40	2.52	4.21	3.33	2.75	3.90	4.09	3.91	3.57
	FA-82	13.8	5.5	4.0	10.5								7.09

Table 2										
Percent of FY84 Seedlings (on Belt) Not Meeting Specifications										
Improper Count	Short Root	Small Caliper	Stem Damage	Poor S/R	Poor Form	Short Top	Root Damaged	Poor Color	Total	
1.75	1.33	.27	.33	.08	.29	.79	2.44	.08	8.08 percent	
21.64	16.52	3.39	4.07	9.89	3.55	9.73	30.22	.99	100 percent	

Table 3			
Full Time Equivalents (FTE) Used In FY84 (Nursery Employees)			
Contract	10.5 days to grade 4.288M	1.01 FTE	
Force Account	12.4 days to grade 4.288M Based on Average Production Rates	3.38 FTE	

Table 4	
Grading Cost/M	
FY82	\$8.55
FY83	9.64
FY84	8.63
FA-FY83	7.80
Support Cost For Two Days Extra Grading If Done By FA	\$0.81



## APPENDIX II

### CONTRACT PERIOD

Performance is estimated to begin February 20, 1984. If weather and soil conditions permit, the minimum daily production will be:

#### Approximate Bed Lineal Foot/Hour

1st day of pulling	666 feet/hour
2nd day of pulling	1,000 feet/hour
3rd & subsequent day of pulling	1,333 feet/hour

Daily pulling production will be limited to 20 percent above the minimum hourly rate subject to prior approval from the Contracting Officer's Representative.

Grading and counting will start one day after the starting of the lifting and boxing portion of the contract. Minimum daily production of seedlings meeting specifications will be:

#### Base Rate/M

1st day of grading	250 - 275M
2nd day of grading	288 - 320M
3rd day of grading	336 - 370M
4th day of grading	350 - 390M

#### Base Rate + 5% for Volume Over Base Rate Max.

1st day of grading	276M +
2nd day of grading	321M +
3rd day of grading	371M +
4th day of grading	391M +

Volume of seedlings lifted will influence the grading operation. If insufficient volume available for full grading work day, the grading operation may be suspended.

Contractor's Notice to Proceed will not be issued until ground and weather conditions are suitable for work. It is understood that weather and tree physiology conditions will dictate contract work schedules.

All work will be performed during the hours of 8:00 a.m. and 4:30 p.m. with 1/2 hour lunch break from approximately 12:00 to 12:30 p.m. No weekend work is anticipated. During the lifting work, there may be instances of early afternoon shut-downs due to hot dry windy weather.

NOTE: One bed consists of 7 rows approximately 3 1/3 feet wide from tree row 1 to row 7. One bed lineal foot is 3 1/2 feet by 1 foot long.

NOTE: For additional information on the clarification of the specifications, contact Don Werminger or Richard Thatcher at (208) 343-1977.

Award will be made to the lowest responsible bidder for both items.

### SPECIFICATIONS

#### DIVISION 100 - GENERAL SPECIFICATIONS

##### 110 - Scope of Contract

The services covered in this contract include the furnishing of all labor, supervision, transportation and incidentals to perform all work necessary to lift seedlings from seedbeds, box tree seedlings, and grade and count seedlings in a packing shed. When deemed necessary by the Contracting Officer or his representative, further loosen soil by hand spading to free seedlings for boxing, in compliance with all terms, specifications, conditions and provisions of this contract.

##### 120 - Description and Location

Services are to be performed at the U.S. Forest Service's Lucky Peak Nursery, located approximately 17 miles east of Boise, Idaho on State Highway 21.

The attached map (Exhibit 2) is intended to show project location and nursery layout only. A more specific work map will be provided to the successful bidder at the prework conference. Exhibit 1 reflects the type and estimated quantity of seedlings to be lifted from each field and counted and graded in the packing shed.

Exhibit 3, Volume of Seedlings, is also attached. It details the approximate volumes of each particular species by field to be lifted.

##### 130 - Government-furnished Property and Services

The Government shall deliver to the Contractor the following listed materials, supplies, property, or services (hereinafter referred to as "Government-furnished property") at the places and times specified below. The Contractor shall be liable for all loss or damage of such delivered Government-furnished property until completion and final acceptance of work required under this contract. If the Government fails to make timely delivery of such Government-furnished property suitable for its intended use, and upon written request from the Contractor, the Contracting Officer shall make an equitable adjustment of contract delivery or performance dates or contract price, or both, pursuant to the "changes" clause of the General Provisions of this contract.

a. Tubs for transporting seedlings.

(1) Tubs are 26 1/2 x 18-3/4" x 10 1/2"

b. Spading for loosening soil.

c. Four grading tables to grade and count on. There are 48 total grading locations.

#### 140 - Contractor-furnished Equipment

The Contractor will provide all supplies and incidental items, other than those specified as Government-furnished, that may be required in the performance of the contract.

#### 150 - Restrooms and Lunchrooms

Although the Government will provide the restroom and lunchroom facilities, the Contractor will be required to sweep both facilities daily, lunchroom tables wiped daily. Toilet paper and hand towels will be restocked daily. All trash will be placed in garbage containers provided by the Government.

#### 160 - Contract Representatives

There will be at least one English speaking, non-working Contractor's Representative for every 11-13 workers.

### DIVISION 200 - TECHNICAL SPECIFICATIONS

#### 210 - Lifting

Seedling stock will be undercut in the beds by Forest Service personnel prior to hand lifting. The undercutting process requires at least two passes by the tractor-mounted cutter/shaker. The Contractor will not begin lifting trees from any undercut area until authorized by the COR or Government Inspector.

#### 220 - Boxing of Seedlings

Burlap will be placed in box so that  $\frac{1}{4}$  will extend on one end,  $\frac{1}{4}$  covering bottom of container, and  $\frac{1}{2}$  extending on opposite side. The long end will then be folded over container so that seedling roots will always be covered. When box is full, burlap ends will be tucked in on all four sides of container. No roots or tops will be exposed.

Seedling beds are to be completely lifted. Leaving hard-to-lift or partially covered seedlings in the beds will not be permitted.

#### 230 - Field Handling of Seedlings

Pullers will properly lift and handle tree seedlings so as to avoid injury or unnecessary exposure to harmful elements.

1. Seedlings will be lifted from the seedbeds by grasping two handfuls of seedlings in the same seedling row at the same time and at the soil line and lifting, with a steady pull, not jerking, them free from the soil. Extreme care must be taken to avoid bending or kinking tree stems.

2. After shaking seedlings to remove all loose soil, the stock shall be immediately placed in the tree box. Seedlings must not be exposed to the open air for more than 20 seconds from the time they are pulled from the ground until they are placed in a box and covered with burlap.

3. Seedlings will not be beat or knocked against any object, in an attempt to remove excess soil from roots.

4. The Government will transport the packed seedling containers from the field to the packing shed, and empty containers to the field.

5. In order to retain the identity of the seedlings, filled tubs will be placed in the seedling bed that the seedlings were pulled from.

6. All layers of trees in each container will be placed in the same direction with no mixing of tops and roots. All containers will be covered.

7. Stockpiling of trees on the ground will not be allowed. Pullers must keep boxes close to them to permit continuity of work and meet the limitation on exposure of trees. In the event of a temporary box and tub shortage, the Contracting Officer or his Representative may, as an interim measure, permit seedlings to be bundled in burlap strips. Specific bundling instructions will be given to the Contractor at that time.

#### 240 - Loosening Soil

Soil conditions exist in some seedbeds where undercut trees are difficult or impossible to pull from the ground without excessive damage to the root system. Under these conditions, the specifications require additional loosening of soil around the roots by the use of spading forks, or some other hand implement that will loosen the dirt and prevent damage to roots.

#### 250 - Separating When Grading

Each seedling will be separated from a group of seedlings in such a manner that all branches and roots of each small seedling are free from any other seedling. The root systems will be down.

#### 260 - Grading

Each seedling will be graded to ensure that it meets acceptable standards. Any seedling not meeting standards will be discarded on the floor. The crew size for grading will be limited to no more than 52 people.

#### 261 - Damage

Any seedling showing damage (ripped roots and/or mechanical damage to the stem, branches, or buds in excess of 25 percent of the diameter of the seedling at the place of damage) will be culled.



#### 262 - Shoot/Root

The shoot/root ratio for acceptable seedlings will be no greater than 2:1. The volumetric displacement of the seedling top will not be more than 2 times greater than the root system. Groundline will divide the shoot and root systems. Any seedling not meeting this standard will be culled.

#### 263 - Root Length

Root measurement will be from groundline to the end of the root system of the suspended seedling. Roots will not be pulled taut to check for root length. See "Grading Standards" for minimum root length standards.

#### 264 - Root Composition

Minimum root composition will be at least main side roots. No "carrot" or single tap root systems will be acceptable for conifer seedlings.

1. Root systems will be free and clean of soil.

#### 265 - Shoot Height

Height will be measured from groundline to the tip of the terminal bud. See "Grading Standards" below for minimum shoot height.

#### 266 - Color

Conifer seedlings will be green in color. Undue yellowish seedlings will not be acceptable. A specific color standard can be better determined at grading.

#### 267 - Diameter

The diameter at groundline will be at least two millimeters.

#### 268 - Form

General form for satisfactory seedlings will be free of forked-top seedlings, kinked root systems, and groundline swelling. Due to some genetic characteristics and traits, acceptable form characteristics for one seedling source may be unacceptable for another.

#### 269 - Grading Standards

	Min. R.L.*	Min. S.H.*	Max. Cal.*
DF	7 in.	2½ in.	2mm
ES	7 in.	2 in.	2mm
WF	7 in.	2 in.	2mm
SWWP	7 in.	3 in.	2mm

\* These sizes may change depending on the extent of growth during the growing season.

Actual specifications will be determined for each source at the time of grading. The above standards are estimates, not guaranteed standards. Refer to Exhibits 4, 5, and 6 for further information on seedlings, their parts, and how the grading measurements will be taken.

#### 270 - Seedling Bundles

Bundles of acceptable seedlings will be placed on the grading belt with the roots extended and all pointed in the same direction at a spot indicated on the grading belt.

#### 280 - Counting

All acceptable seedlings will be counted in groups of ten. When a group of ten acceptable seedlings has been counted, the group will be placed on the belt in such a manner that all the root systems face the same direction and the groundline of seedlings in the group coincide.

#### 290 - Final Handling

##### 291 - Tubs

Contractor will be responsible for taking tubs of seedlings from the upper roller conveyor next to the grading belt. Empty tubs will be placed on the lower roller conveyor. All tubs will be empty before placing on the lower roller conveyor.

##### 292 - Covering Seedlings

The wet burlap covering the seedlings will cover the seedlings during any work break, such as lunch, coffee break, trips to the restrooms, etc.

##### 293 - Seedling Source Changes

No grading will be started until authorized by the Inspector. This will eliminate the possibility of mixing sources.

##### 294 - Cull Seedlings

No more than one half of one percent satisfactory seedlings may be discarded in the grading operation.

#### DIVISION 300 - INSPECTION AND ACCEPTANCE

##### 310 - Inspection Procedure

Pursuant to Clause 13, Part A, Form 6300-38, General Provisions, the Government will determine and record the Contractor's daily accomplishment by lineal foot during the period of the lifting portion of the contract. For the grading portion of the contract, the Government will determine and record the Contractor's daily accomplishment by each 1,000 group of seedlings that are graded and counted.

### 320 - Quality Inspection Requirements

Lifting quality inspection will be in compliance with the technical provision of Division 200, subdivision 220.

Grading and counting quality inspection will be in compliance with the technical specifications of Division 200, Subdivision 260. No less than 1 percent of the cull seedlings will be inspected for satisfactory seedlings. Inspection will be made in groups of 40 seedlings. If more than 5 percent unsatisfactory seedlings are found in the sampled culls, a 10 cents per seedling fine will be assessed.

Should any of the following infractions occur, deductions from payments will be made for property damage at an assessed penal sum of \$3.50 per incident:

#### Lifting

- a. Lifting less than two handfulls from same row.
- b. Excess soil on seedling roots.
- c. Abuse of seedlings to remove excess soil.
- d. Failure to properly cover lifted seedlings.
- e. Piling seedlings on ground.
- f. Exposing roots for longer than 20 seconds.
- g. Leaving any seedling in beds.
- h. Walking on seedlings.
- i. Over or under filled containers.
- j. Failure to place all trees in the same direction, mixing top and roots.
- k. Pulling seedling in a jerky or snapping motion.
- l. Filled tubs not placed in beds from which the seedlings came from.

#### Grading and Counting

- a. Leaving tree tubs uncovered.
- b. Leaving seedlings in boxes.
- c. Abuse of seedlings to remove excess soil.
- d. Groundlines do not coincide.
- e. Seedlings not separated.
- f. Bundles not aligned on belt.

The Inspector will promptly notify the Contractor or his Representative at the time the infraction is observed. The infraction will be promptly recorded in the COR's daily diary.

### DIVISION 400 - MEASUREMENT AND PAYMENT

Lifting - The lifting record times the bid price per lineal foot, minus any fines for the above-listed infractions, will be basis for payment on the lifting portion of the contract.

Grading and Counting - A sample of not less than one percent will be taken of all graded seedlings coming over the belt. The percentage of sampled trees not meeting the specifications is then multiplied times the gross daily production volume. This amount plus any fines assessed for the above-listed infractions will then be deducted from the gross daily production volume to arrive at the total amount to be paid for at the applicable bid price. If the percentage of sample seedlings not meeting standards in Section 250 and 260 is less than 9 percent, full pay will be given.

#### 410 - Bid Item No. 1B Only

It is mutually agreed that it is inherent in the nature of this contract that some changes in the number of seedlings as provided in the Schedule of Items may be necessary during the course of the contract and that it is the essence of the contract to recognize a normal and expected margin of change within the meaning of the "Changes" clause of Form 6300-38 as not requiring or permitting any adjustment of contract prices, except: (1) When the number of seedlings in Bid Item No. 1B is increased to more than 125 percent of the quantity stated in the Schedule of Items, then either party to the contract, upon demand, may be entitled to an equitable adjustment on that portion above 25 percent of the quantity stated in the Schedule of Items: or (2) when the number of seedlings of Bid Item No. 1B of the contract is reduced to less than 75 percent of the quantity stated in the Schedule of Items, then either party to the contract, upon demand, may be entitled to an equitable adjustment for the quantity of seedlings actually accepted.



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LIFT AND PACK PROCEDURES AT THE J. HERBERT STONE NURSERY

Fred Zensen

ABSTRACT: Provides an explanation of methods used for lifting and packing of tree seedlings at the J. Herbert Stone Nursery. Procedures outlined include lifting guidelines, processing, techniques, and review methods.

#### INTRODUCTION

Lift & pack is the culmination of 2-3 years of nursery work. It is the climactic moment in the life of a tree seedling at a nursery. This is the time when the fruits of our labor are actually seen. No matter how often you walk the seedbeds and observe, dig tree samples, or count seedlings, you cannot truly know how your stock measures up until it is lifted, graded and packed. When the numbers of packed seedlings are tabulated, then the nursery manager can accurately figure the income for the year. Therefore, the importance of the lift and pack operation is paramount in tree seedling nurseries.

#### PRE-LIFT PREPARATION

At the J. Herbert Stone Nursery, the actual lift and pack season is late November through March, with target dates being December through February. The capacity of J. Herbert Stone Nursery is 36 million 2-0 tree seedlings per year.

Planning for lift and pack begins with the preparation of our lifting contract in early July. Estimates of the footage to be lifted are made and contract is submitted to the business management group for publication and solicitation.

Personnel required to lift and pack 36 million seedlings is 230 employees: 25 permanent, 205 temporary. This includes our office staff. The bulk of the 230 employees are hired for processing of seedlings; grading, packing, storage and shipping, and quality monitoring.

Our next order of business is the annual clients meeting held in October. This meeting is a two-day affair which allows our clients an opportunity to view their stock and compare abstract inventory numbers and scatter diagrams to tangible tree seedlings. It is difficult to convey a picture of

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Paper presented at combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Coeur d'Alene, ID, August 14-16, 1984.

Frederick Zensen is Nursery Superintendent Assistant, J. Herbert Stone Nursery, USDA Forest Service, Central Point, OR.

seedling morphology to clients in a numeric matrix, therefore, we request our clients to make every effort to attend this meeting. The second day of our meeting is a discussion of various topics of mutual interest to our clients and ourselves. Attendance often numbers 85 or better. Our clients are National Forest Ranger Districts in Oregon and California as well as Bureau of Land Management Resource Areas in Oregon and number about 70. With as diverse a group of clients as this, we find it very helpful for all concerned that we are all on a relatively similar wave length regarding how we do business at J. Herbert Stone Nursery.

Of paramount importance at our clients meeting is the distribution of our seedling order form. These forms are used as our lift and pack request and the source documents for billing and order explanations. Information provided on the form includes desired seedlings, grading specifications, special instructions (moss, bundling, double sort, transplant, early or late lifting dates), and billing instructions. These forms are to be returned to the nursery no later than November 15.

#### LIFTING

Lifting begins in early December, weather permitting. Often we must cease operations due to rain or frosty, frozen conditions. One must realize that nursery managers tend to prefer odd weather conditions during this time of the year. Foggy days with temperatures in the mid-40 degree Fahrenheit range make nursery managers get all misty eyed. Scheduling of seedlings to be lifted is accomplished primarily on a species basis, although December is somewhat mixed. With clients from the Oregon coast to the Malheur mountains of Eastern Oregon, the needs are quite varied. As it usually works out, everyone wants their stock lifted at the same time. We make every effort to honor special requests but mass lifting is the norm.

Lodgepole pine and western larch are lifted first in December. These species usually require long-term storage, as they are generally planted on east-side Cascade sites. Long-term storage can often mean up to 6 months in the coolers. This requires two critical features. First, ideal storage conditions--95 percent relative humidity, 33-36 degrees Fahrenheit and second, a storage monitoring system that features an alarm when conditions are less than or more than ideal. At J. Herbert Stone Nursery, we have equipment which meets both conditions and is operable. Another component of proper long-term storage is the condition of the seedlings themselves. Have they been mishandled? Is there too much moisture on the foliage? These points all contribute to the well being of seedlings stored



for long periods of time. Our clients have had excellent results with stock stored for up to 6 months. Lakeview Ranger District, Fremont National Forest, planted lodgepole pine lifted in December as late as July 4, with 98 percent survival and acceptable growth.

Much of our 1-0 for 1-0 ship is lifted in December. We normally work until Christmas week and cease operations until the New Year's celebration is completed. Douglas-fir, ponderosa pine, Abies species, sugar pine, western white pine, western redcedar, incense cedar and spruce are lifted in this order if at all possible.

Lifting guidelines at the J. Herbert Stone Nursery have been established based upon historical records and professional opinion. To date, we have no researched lifting windows, but rather extrapolate the Oregon State University Douglas-fir guidelines of December 15 - March 15. Our track record has borne out our procedures. We will be actively participating in a number of lifting window studies this next year. We hope they will provide us with data to support what we are doing today. Guidelines have been established for Plant Moisture Stress during the lifting operation. These guidelines have been separated into early morning and daytime rates. In the early morning when frosty or frozen conditions tend to abound the applicable guidelines are 10-15 bars on bed seedlings. After seedlings have been lifted and are in containers for at least 15 minutes, PMS is again taken. If PMS has dropped 3 bars or more, lifting continues with PMS taken every 15 minutes. If PMS drops by 3 bars the second time, testing is ceased unless there is a drastic weather change. During the day, seedling PMS may rise due to evapotranspiration, particularly on sunny and/or windy days. Higher PMS may be accepted under these conditions: 15 bars Douglas-fir and pines. When PMS reaches 15 bars in Douglas-fir or 18 bars in the pines, PMS will be taken on seedlings which have been lifted and in a seedling container for 15 minutes. If PMS has dropped 3 bars or more, lifting continues. If at any time PMS exceeds these conditions, the lifting supervisor is notified and the appropriate action is taken.

Weather conditions are given the following definitions during lifting:

Ideal - overcast or foggy; temperature 45 °F; relative humidity 80 percent or higher; wind <5 mph.

Favorable - high overcast, 50 percent sunny; temperature 45-65 °F; relative humidity 60 percent or greater, wind <5 mph.

Somewhat Favorable - cloudy but 50 percent sunny; temperature occasionally rises over 65 °F; relative humidity 50 percent or greater; wind <3 mph.

Unfavorable - anything other than above.

#### PROCESSING OF SEEDLINGS

In the packing shed, seedlings are graded, pruned, packed, sampled for testing, and sent to cold

storage. Procedures and seedlings are monitored very carefully. In fact, we have a staff of six people whose sole function is quality monitoring. Quality monitoring consists of checking the seedling morphological characteristics for compliance with the clients' orders, monitoring bag counts and root length, PMS and adherence to nursery grading standards for quality. This information is posted for all to see as well as provided immediately to the work leader responsible for the particular grading table monitored. Ten percent of the seedlings are also sent to independent testing laboratories for determination of frost hardiness, root growth capacity, and stress analysis.

After the seedlings are brought in from the field, they are immediately placed in pre-cooler storage until they are processed. This pre-cooler storage is usually for a minimum of 48 hours. PMS is monitored to ensure that it is at or below 5 bars. Seedlings are then brought into the grading tables as needed to complete the order. Once processing is completed, they are immediately placed in cold storage until shipped to our clients. Storage conditions are maintained at 33-35 °F and 95 percent or better relative humidity. These are considered optimum conditions for seedling storage.

#### SEEDLING STORAGE

Seedlings are kept in storage until they are requested by our clients. This can often be as long as six months. Storage conditions are constantly monitored and an alarm system is in operation to notify us of equipment failure. A constantly updated inventory is maintained. As shipping requests arrive, a schedule is developed. Seedlings are shipped by contracted carrier in a refrigerated van. Seedlings are generally shipped palletized. This eliminates unnecessary handling which could place additional stress on the seedlings. It also allows our clients to unload the trucks with a forklift and place the seedlings in interim storage undisturbed.

#### SITE VISITATIONS

During the field season, members of the Nursery staff visit with our clients on site for the purpose of review of nursery stock, problem solving and prevention, and performance of J. Herbert Stone Nursery seedlings. We attempt to visit at least six clients per year. We are also available to respond to those clients who request such a visit. These visitations are beneficial for both parties. Nursery personnel are given the opportunity to observe planting sites and operational reforestation practices, as well as get a better idea of techniques and responsibilities of clients regarding seedlings. We have an exchange of ideas and listen to the needs, wants, and desires of our clients. They in turn see the interest we have in the reforestation process and our willingness to respond to their needs. These visits have done quite a bit to foster good communication and cooperation between ourselves and our clients.



## REVIEWS

To review our process, the season can be divided into different areas. First is the planning stage which actually begins in June prior to lifting. Second is the implementation stage including contract award, lifting, processing, storage, shipping, and cleanup. Third is review. This final stage is in many respects the most important. It includes not only the official testing results, but our site visitations and clients meeting after field season. Another method of checking what and how we accomplish is by a continuous critique of our methods. This is accomplished by weekly meetings and through a participatory management technique known as quality circles. Members of our work force volunteer to serve on one of two eight-member quality circles. The circles are facilitated by a nursery employee trained for this task. The mission of these circles is problem solving and problem prevention. We have been quite successful with this technique and have established a permanent quality circle consisting of our full time employees which meets during the rest of the year.

Another method of review is our mid and end of season critiques. These are divided by work area. The employees in the individual areas present their views of what worked and why, what did not work and why, and possible methods of improvement. Through these techniques, we have been able to constantly improve and refine our methods of doing business. Not all ideas are implemented, but many more are than not. Our employees are the experts at the particular task, and more often than not, are more efficient at the task than we as managers can envision. Employee involvement will enhance a project.

## CONCLUSION

Lift and pack season at the J. Herbert Stone Nursery is a very busy time of the year. It entails total involvement by all nursery personnel. The commitment to produce high-quality, growing and surviving seedlings at the J. Herbert Stone Nursery is total. We are constantly seeking methods to improve our seedlings. In addition to our seedlings, our most important resource is our personnel and they are fully aware of the philosophy and commitment to quality which exists at the J. Herbert Stone Nursery. We feel that our methods and results are top notch and the growth and survival of our seedlings bear this out. Yet we will not stagnate with our procedures and as new, more efficient, more scientific approaches become available we will alter our methods to comply with these, but not at the sacrifice of quality.

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## IMPACTS OF NURSERY PROCESSING ON THE SURVIVAL AND GROWTH

## OF 2+0 DOUGLAS-FIR SEEDLINGS

Robyn L. Darbyshire

**ABSTRACT:** Three handling treatments compared seedlings during the time period from just before lifting to the time when seedlings are placed in nursery cold storage after grading and packing. The handling treatments were as follows: (1) the indoors treatment--"conventional" nursery handling with seedlings held for 48 hours in a cool, humid room between lifting and grading; (2) the outdoors treatment--"conventional" nursery handling with seedlings held outdoors on a covered dock for 48 hours between lifting and grading; and (3) bedpacking, where seedlings are lifted and taken directly to cold storage without the extra handling involved in grading and packing.

Bedpacked trees had the lowest plant moisture stress (PMS) and temperature during the holding period. There was no difference in PMS for the indoors and outdoors treatments, but the indoors treatment did keep the seedlings at a lower temperature than the outdoors treatment.

Planted seedlings showed no significant differences in budbreak or survival due to handling treatment after one growing season, but bedpack seedlings had a significantly longer ( $p=0.01$ ) new leader and new leader dry weight than the other two treatments. Though not significant, the same trend occurred for dry weight of new laterals and total shoot dry weight at the end of the first year. The length of new terminal growth was measured for the second and third growing seasons and showed no significant differences between treatments.

More work at different nurseries and in different outplanting environments is needed before strong recommendations can be made about bedpacking versus conventional handling. Greater attention to the management of temperature and plant moisture stress during nursery handling may eliminate differences between conventional handling and bedpacking.

Paper presented at combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Coeur d'Alene, ID, August 14-16, 1984.

Robyn L. Darbyshire is Research Assistant, Nursery Technology Cooperative, Oregon State University, Corvallis, Oregon.

## INTRODUCTION

This project studied the seedling production process from the time just before undercutting in the nursery bed to the time that graded seedlings are placed in nursery cold storage. This is a period in nursery seedling production when most of the physical handling of seedlings occurs. During this time, seedlings may experience not only physical abuse, but also water and temperature stress. Temperature and plant moisture stress (PMS) can be monitored to prevent damage, but there are currently no methods of quantifying or monitoring physical abuse.

Differences in seedling handling that may cause differences in plantation performance can be very subtle, yet produce rather pronounced effects. Mullin (1974) studied a red pine (*Pinus resinosa*) plantation in Ontario, Canada, for 20 years. This plantation was established for a study that compared two planting crews, two types of packaging, and different lengths of unrefrigerated storage. He found that it took 20 years for a difference in planting crews to be significant. This difference amounted to a 14% greater volume per acre for one of the crews, and was due to a difference in handling, not a difference in survival. After one year, it was apparent that trees held for a longer period in unrefrigerated storage had lower survival. After five years, height growth was also significantly affected by the length of the unrefrigerated storage.

Albert and others (1980) looked at the effect of packing on radiata pine (*Pinus radiata*). They broke down the packing/shipping process into five steps: (1) lifting; (2) transporting to the packing shed; (3) grading and packing seedlings into boxes; (4) packing boxes into crates for shipping; and (5) transferring seedlings to planting bags at the planting site. The growth and survival of seedlings removed from the process after completing (1), (1) through (4), and (1) through (5) was compared. First-year mortality increased from 0.6% if removed after (1) to 1.6% after (4) to 7% if removed after (5). Mean height after one year decreased from 71 cm if removed after (1) to 50 cm after (5). Third-year results maintained these differences and also showed a decrease in caliper from 28 mm after (1) to 21 mm after (5). Values for height and caliper for trees removed after (4) were about midway between the mentioned figures.

Trewin (1978) also looked at radiata pine in terms of reducing damage by eliminating steps in



the handling process. A system was devised where seedlings are lifted directly into boxes that also serve as tree planting "bags". The result has been greater survival and growth.

The two studies cited here on radiata pine show that the handling of seedlings at the nursery plays a role in decreasing the ability of a seedling to grow vigorously after outplanting. These studies and that of Mullin also show that handling after the seedlings leave the nursery is also important in this respect.

Another relatively new idea in stock handling is the inclusion of a "pre-processing cooler" in packing sheds. The D. L. Phipps State Forest Nursery near Elkton, Oregon, has a pre-processing cooler--a separate room for holding the unprocessed seedlings between lifting and grading. The temperature is maintained at about 40 degrees F and the relative humidity is kept between 80 and 90%. Before the new facility was built, the unprocessed seedlings were held outside on a covered dock. The pre-processing cooler offers a possible improvement by keeping the seedlings at a fairly constant temperature in a high humidity environment.

The differences between seedlings packed in a packing shed and seedlings packed at the nursery bed have not been studied for Douglas-fir, nor has a comparison been made of seedlings stored outdoors between lifting and grading and seedlings stored during this same time in a facility that maintains a fairly constant cool temperature and high humidity. Answering these questions could be important in determining the design of future seedling processing facilities, as well as in improving the physiological condition of out-planted seedlings.

## OBJECTIVES

The objectives of this study were as follows:

1. To characterize the temperature and the plant moisture stress of bare-root stock in the time period from just before lifting until the seedlings are placed in nursery cold storage.
2. To compare growth and survival of trees handled in three different ways at the nursery:
  - A. Trees handled conventionally with the use of a pre-processing cooler to hold stock between lifting and grading. (The "in-doors" treatment.)
  - B. Trees handled conventionally, but stored outdoors between lifting and grading. (The "outdoors" treatment.)
  - C. Bedpacking.

## PROCEDURES

The seedlings used for this study were from a 2500 foot elevation in seed zone 072. They were lifted at the D. L. Phipps State Forest Nursery in Elkton, Oregon, in February of 1981. A diagram of the handling and planting is shown in Figure 1. This process was repeated on 4, 10, and 25 February 1981. Seedling temperature and PMS were monitored during the handling process at the steps shown in Figure 2. PMS was monitored with a pressure chamber (PMS Instrument Company) and temperature was monitored with an eight-inch-long stem dial thermometer (Weston Co., calibrated from 25 to 125 degrees F).

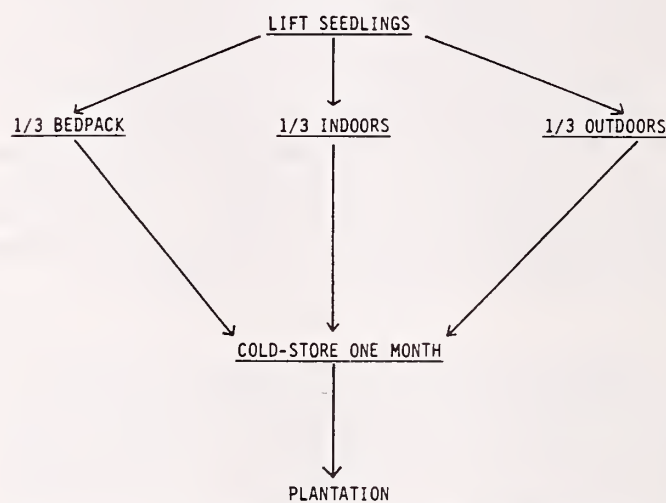


Figure 1.--A diagram of the experimental procedure. This was repeated on 4, 10, and 25 February 1981.

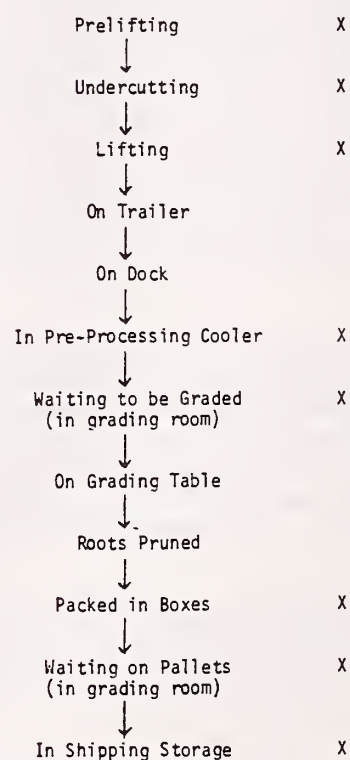


Figure 2.--Steps in nursery handling at the D. L. Phipps Nursery. An "X" indicates steps where monitoring of PMS and temperature occurred for this study.

Undercutting occurred if PMS was greater than 10 bars. The seedlings were lifted into plastic tubs (for the indoors and the outdoors treatments) or cardboard shipping boxes (for the bedpack treatment) 1 1/2 hours after undercutting. The trees were then delivered to their respective holding places. Forty-eight hours later, the seedlings from the indoors and the outdoors treatments were brought into the grading room for a 20-minute delay before grading. The seedlings were graded by nursery graders to a minimum 3-mm caliper and 6-inch shoot length. They were bundled in groups of 50 before being root-pruned to 9 inches. Seedlings were then packed in boxes and placed in cold storage. The bedpack seedlings were graded and root-pruned at the time of planting.

The outplanting site was planted in a split-plot design with four replications. Whole plots were lifting dates and sub-plots were handling treatments. Fifty trees were planted per plot for a total of 1800 trees. Trees were planted on a 2 x 2 foot spacing on a slightly east-facing aspect. The site was a former grassy field in the McDonald State Forest. The site was plowed about one month before planting. The seedlings were planted with a shovel, and all trees were planted by the same person.

Initial morphology was determined for each lifting date and handling treatment combination. Height growth, budbreak, survival, and morphology at the end of the first growing season were measured. Height growth was subsequently remeasured at the end of the second and third growing seasons.

## RESULTS AND DISCUSSION

### Plant Moisture Stress During Handling

Guidelines for interpreting PMS of nursery seedlings have been established by Daniels (1979) and Cleary (personal communication). It is generally recommended that PMS be kept less than 5 bars at all times between undercutting and planting.

A comparison of the PMS results is shown in Figure 3. For all treatments, PMS tended only to decline after undercutting. The reason why PMS declined for the indoors and the outdoors treatments on the first lifting date and then started to increase again, peaking at about six to eight hours after undercutting, is unknown. The increase in PMS after grading for the first lifting date may be due to a more gradual drying-out over the 48-hour holding period than to drying during the grading itself. The monitoring for this study was not intensive enough during grading to determine what, if any, drying occurs during grading. The increase in PMS for the indoors treatment during the third lifting date occurred as the seedlings dried out after being watered and serves as an illustration that water loss can occur in the pre-processing cooler.

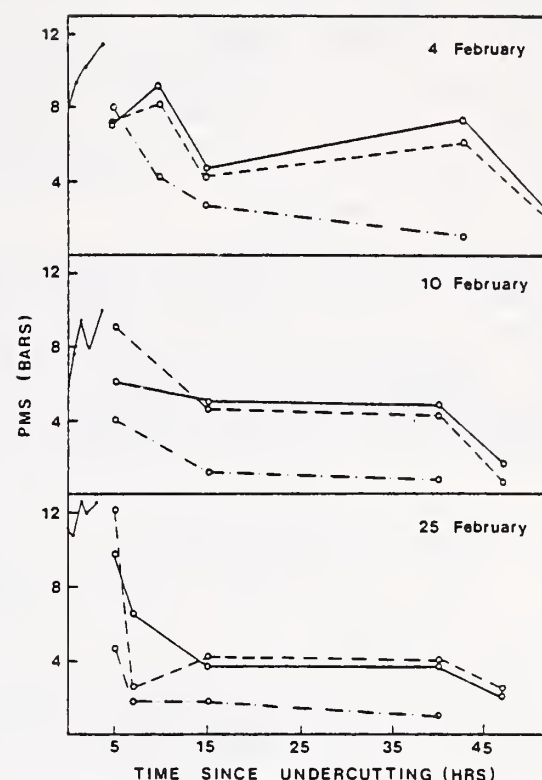


Figure 3.--Seedling Douglas-fir PMS with time for the three handling treatments: indoors -----, outdoors ———, bedpack - · - · - ·. The solid line with the filled circles represents the time before the treatments were separated. Each point is the mean of three to four seedlings.

It is interesting to note the similar PMS measurements for the indoors and the outdoors treatments. However, fog often is present until 11 a.m. or noon in this part of Oregon, and this may be the reason for similarity. For nurseries in drier climates (i.e. the east side of the Cascades) there may indeed be a difference in PMS between these two types of handling.

The most rapid decline in PMS for all treatments occurs once they are placed in the shipping boxes. A relative humidity of close to 100% inside the boxes is probably partly responsible for this decline. For the indoors and the outdoors seedlings, the rate of PMS decline was much slower versus the rate of PMS decline for the bedpack seedlings. This study was not designed to investigate this particular question, but these results do suggest that the indoors and the outdoors seedlings have lost some of their capacity to internally adjust their PMS, perhaps due to lower moisture content after 48 hours of holding in an environment that allows water loss from the seedling.

### Temperature During Handling

Temperature guidelines for seedling handling are based on general biochemical knowledge of the effect of temperature on essential plant enzyme systems (i.e. the enzyme systems of photosynthesis and respiration). Length of time at a certain temperature is important too, as the longer the time at an unfavorably high temperature, the greater the risk of incurring damage to tissues



or to enzyme systems and the more rapid the loss of carbohydrate reserves due to respiration. A tentative temperature guideline for tree seedlings can be found in Cleary and DeYoe (1982). The fluctuation of temperature is also important to note, as repeated fluctuations can dehydrate seedlings. In general, however, seedling temperature should stay above 40 degrees F for as little time as possible.

A comparison of the results in terms of temperature is shown in Figure 4. The course of temperature for the three treatments is fairly close to what might be predicted. Inconsistencies in the graphs were probably due to dead air spots in the pre-processing and the storage coolers.

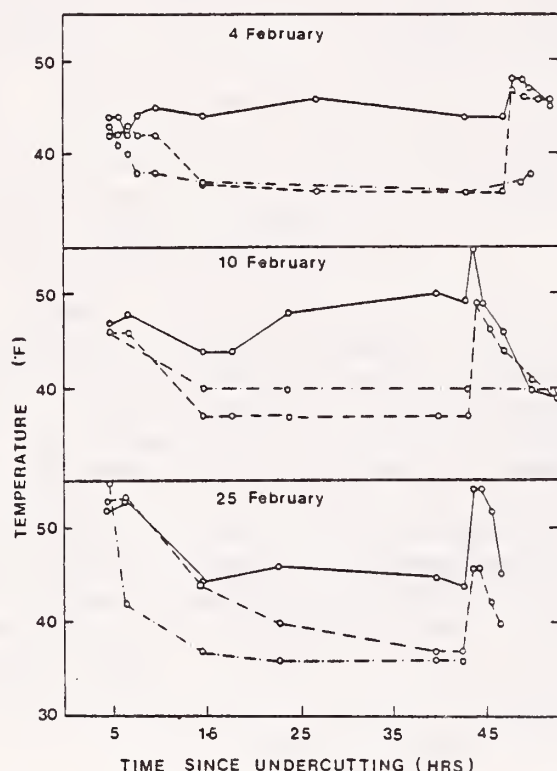


Figure 4.--Temperature of Douglas-fir seedlings with time for the handling treatments: indoors -----, outdoors -----, bedpack -.-.-.-. Each point is the temperature of one box or tub of seedlings.

The most important differences in temperature occurred at the time of packing, about 45 hours after undercutting. The temperature inside the box tends to rise due to warm air (55-62 degrees F) being "packed" in with the seedlings. The indoors treatment, however, tended to have a higher absolute temperature increase versus the outdoors treatment, as the indoors trees are cooler to start with. This lower initial temperature may also cause the indoors seedlings to reach room temperature more rapidly if they are left at a warmer temperature for a longer period of time (i.e. if they spend a longer time in the grading room before being packed).

#### Initial Morphology

Overall, caliper averaged 4.7 mm, the average shoot length was 36.8 cm, shoot dry weight averaged 4.5 g, the average root length was 31.1 cm,

and root dry weight averaged 2.4 g. These seedlings were well above the minimum grading standards of 3 mm caliper and 15.2 cm shoot length.

#### Budbreak

All seedlings burst their buds. An analysis of days to 50% budbreak showed no difference between treatments.

#### Survival

First-year survival was high--mortality was due primarily to rabbits. Maximum mortality in any row due to causes other than rabbits was 6%. There was no appreciable decrease in survival in the second through fourth growing seasons.

#### First-Year Growth

The analysis of variance showed the length and the weight of the new terminal growth to have been significantly affected by the handling treatment ( $p=0.01$ ) (see Table 1). When the treatment means were compared using Fisher's LSD (Ott 1977), the bedpack trees were found to have a longer new terminal (6.9 cm vs 6.1 cm) and a heavier new terminal (0.51 g vs 0.41 g). The treatment means for the indoors and the outdoors treatments were not significantly different. The results were the same when initial height was used as a covariate to help account for the initial differences in size.

Table 1.--Treatment means for Douglas-fir seedlings in the plantation study. For a given dependent variable, means followed by the same letter are not significantly different at  $p=0.01$ . Each mean is the average of 120 seedlings. Treatment means are unadjusted for initial height.

DEPENDENT VARIABLE	INDOORS	TREATMENT OUTDOORS	BEDPACK
CALIPER (mm)	6.0	6.0	6.2
2+0 SHOOT WEIGHT (g)	5.75	5.55	6.16
NEW TERMINAL LENGTH (cm)	6.2 a	6.0 a	6.9 b
NEW TERMINAL WEIGHT (g)	0.42 a	0.41 a	0.51 b
NEW LATERAL WEIGHT (g)	2.72	2.55	3.07
TOTAL SHOOT WEIGHT (g)	8.89	8.51	9.74
NEW LATERAL PLUS NEW TERMINAL WEIGHT (g)	3.15	2.96	3.58

Even though treatment was not significant for the other growth measurements in Table 1, a trend is evident--the bedpack seedlings tended to be larger at the end of the first growing season, even when initial height was used as a covariate. The next largest seedlings were from the indoors treatment, and the smallest were from the outdoors treatment, but the difference between the indoors and the outdoors treatments was small.

## Second- and Third-Year Growth

The length of the new terminal was measured in 1984 for the 1982 and 1983 growing seasons. The analysis of variance showed no significant differences between treatments. Mean height for all treatments in 1982 was 8.6 cm and in 1983 was 19.5 cm.

## CONCLUSIONS

1. There were no significant differences between the indoors and the outdoors treatments. This may not be the case at a nursery in a drier climate. The high relative humidity and the fog at Elkton during lifting probably helped to minimize any growth differences between these two treatments due to plant moisture stress. Also, day-time temperatures outdoors were not over 60 degrees F during the experimental lifting, and seedlings did not remain at this temperature for a very long period of time (Fig. 4). Severe freezing temperatures at night also did not occur. This does not mean that the pre-processing cooler is not needed at Elkton, as warmer, drier lifting years have been known to occur. The fact that the pre-processing cooler is there and the knowledge that it is there for seedling protection will possibly promote better handling by nursery employees because they are more aware of the need for care and attention to detail in seedling handling.

2. Bedpacking may result in more seedling growth. Treatment differences may become even more accentuated after several growing seasons. Why might these differences occur? Certainly there is less handling involved and the bedpack seedlings are also exposed to less temperature and plant moisture stress prior to planting. New terminal length in the first growing season was significant, but not in the second or third growing seasons. Total height may be a more appropriate variable for subsequent growing seasons. A longer term study and other changes in nursery practice would be required before bedpacking is used operationally, but its use may result in better seedling growth.

3. More severe environmental conditions on the planting site may have emphasized handling treatment differences more. The seedlings planted in the plowed field were not subjected to much water stress (maximum pre-dawn PMS was 8 bars) and more stress may have provided larger differences between treatments. A site with moderate competition may provide a better environment to show early differences.

4. Attention to factors during handling that affect temperature and plant moisture stress is important in preventing possible damage. Control of temperature and plant moisture stress will help produce the best quality seedlings possible and may decrease any differences between bedpacking and conventional handling. For example, the lifting conditions for this study allowed PMS levels to occur that, according to PMS guidelines, should have been alleviated by watering.

If seedlings in the indoors and the outdoors treatments had been watered to keep their PMS less than 5 bars at all times between lifting and cold storage, differences between treatments may not have been significant.

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## COLD STORAGE INCREASES RESISTANCE TO DEHYDRATION

## STRESS IN PACIFIC DOUGLAS-FIR //

James L. Jenkinson and James A. Nelson

**ABSTRACT:** Seedlings of coastal California Douglas-fir grown at the Humboldt Nursery were lifted in January and February and investigated for the effects of a standard dehydration stress applied either before or after cold storage or both. Survival potential and top and root growth capacities of stressed and unstressed seedlings were evaluated in a greenhouse in May, and field survival and growth were determined on a nearby planting site. Survival potential averaged 53 percent for seedlings stressed before storage in January, compared to 97 percent for seedlings stressed after storage. The survival potentials, growth capacities, and field performances of seedlings stressed after storage approximated those of unstressed seedlings. Apparently, seedlings stored in midwinter doubled their resistance to dehydration stress during storage, and seedlings stored in late winter maintained their high resistance. The evidence suggests that, for sources from northern California and southwestern Oregon, stress tests to evaluate survival potentials of Humboldt planting stock should be done after cold storage, shortly before spring planting, if at all.

## INTRODUCTION

Field survival and growth of 1-0 and 2-0 bareroot seedlings from the Humboldt Nursery, located near McKinleyville on California's north coast, have proven the efficacy of overwinter cold storage for coastal and inland seed sources of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) on the Pacific slope (Jenkinson 1984). Storage at 0° to 1° C (32° to 34° F) completes the chilling that seedlings lifted in late autumn and early winter need to overcome dormancy and promote shoot growth, and it results in seedling root growth capacities that enable successful plantation establishment (Jenkinson and Nelson 1978, 1983).

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Because operational circumstances sometimes compromise seedling production, harvest, or cold storage, many of Humboldt Nursery's clientele, like those of other nurseries, want independent tests of the physiological quality of planting stock. The aim of such tests is to eliminate the economic losses that result when planted stock fails the minimum first-year survival standard. The present standard in the Pacific Northwest and Southwest Regions is 80 percent (860 seedlings/ha or 348/acre for a spacing of 3 m or 10 ft).

One measure of seedling quality that can be used to estimate survival in the field is root growth capacity (RGC). This test requires three things to predict survival: RGC must be determined after cold storage, near planting time in spring; the critical threshold values of RGC must be known or estimated for the various planting sites; and the seedlings must be planted when the soil is warm enough to permit water uptake and root growth. RGC will change in cold storage, depending on the interaction of seed source and nursery lifting date (Jenkinson 1978), and planting any site when the environment is not conducive to immediate water uptake and root growth will reduce seedling survival (Jenkinson 1980).

Another often used test of the quality of planting stock destined for the Pacific slope assesses the effect of a dehydration stress on subsequent seedling survival in a standard greenhouse or growth room environment (Hermann and Lavender 1979, Lavender and others 1980, Ritchie 1984). This test is used to predict field survival, but the relation of greenhouse survival to field survival is uncertain, and practically unexplored. In one instance where the relation was looked at in southwestern Oregon, survival after one summer was unrelated to survival in the stress test (table 1). Stress tests of Douglas-fir for the Gold Beach Ranger District predicted unacceptable survivals for 5 out of the 7 Humboldt lots evaluated. The general recommendation to not plant lots testing less than 70 percent created a dilemma, because the stress survival of these five lots ranged from 3 to 50 percent. The District chose to plant all lots. Their first-year field survival averaged 84 to 97 percent, and the lowest survival on any planting site was 60 percent.

This failure to predict field survival may be explained if seedling sensitivity to dehydration stress is partly dependent on lifting date and

Table 1.--Stress test and field survivals of Douglas-fir lifted in adjacent nurseries and planted on the Gold Beach Ranger District, Siskiyou National Forest, southwestern Oregon, 1980

Nursery, lifting date, and seed source code	Test survival <sup>1</sup>		Planting <sup>2</sup>		Field survival <sup>3</sup>	
	No stress	Stress	Sites	Times	Mean	Range
Humboldt, Jan 2-3	-----Pct-----				-----Pct-----	
081.15	100	70	7	Feb 1-Mar 13	84	76-100
081.20 (1)	100	20	2	Jan 14-Feb 12	97	96-98
(2)	100	80	6	Feb 3-Feb 26	86	75-97
(3)	100	43	4	Jan 26-Feb 23	94	85-100
(4)	90	30	5	Feb 22-Mar 13	87	78-96
081.33	93	3	2	Jan 25-Feb 11	95	94-96
081.35	100	50	10	Feb 24-Apr 26	85	60-100
Alder Grove, Feb 6-8						
081.15	100	93	5	Mar 2-Apr 14	94	89-95
081.20	100	100	2	Feb 24-Mar 1	95	95-96
081.25	83	77	2	Mar 24-Mar 28	95	89-100
	Mean	Mean	Total	Range	Mean	Range
Humboldt, Jan 2-3	99	42	36	Jan 14-Apr 26	90	81-98
Alder Grove, Feb 6-8	94	90	9	Feb 24-Apr 14	95	91-97

- <sup>1</sup> Two-month survivals from stress tests run by Oregon State University.  
<sup>2</sup> Soil temperatures at planting time were 5° to 10° C (41° to 50° F).  
<sup>3</sup> First-year surveys run by Gold Beach Ranger District (Sep-Nov).

time in storage. Stock from a transplant nursery (Alder Grove) adjacent to the Humboldt Nursery was lifted and tested 1 month later than the same or similar sources at Humboldt (table 1). The survival potential of Alder Grove stock after stress treatment averaged more than twice that of Humboldt stock, yet survival on most of the Humboldt planting sites was as high as that on the Alder Grove sites. The earlier sampling and testing of Humboldt stock could account for its lower stress test survival, because Alder Grove has the same climate and soil as Humboldt, and the stock from both nurseries was packed, stored, and shipped by Humboldt.

With this background, we ran three tests to explore the hypothesis that lifting date and cold storage affect resistance to dehydration damage in 2-0 seedlings of Pacific Douglas-fir grown in the Humboldt Nursery. This paper reports the findings and discusses their implications for assessing planting stock quality.

#### MATERIALS AND METHODS

Seedlings were from a coastal seed source in northern California, near an altitude of 610 m (2000 ft) in seed zone 091 on the Gasquet Ranger District, Six Rivers National Forest. At Humboldt Nursery, 2-0 seedlings were lifted in contiguous plots on January 12 and again on February 9, 1981. For each lifting, seedlings were washed free of soil, culled to a stem diameter of 4 mm, root-pruned 23 cm (9 inches) below the cotyledon node, sorted into 38 sets of 10, and stored to May 10 in polyethylene bags at 0° to 1° C (32° to 34° F). Sets were randomly drawn for dehydration stress treatments and subsequent tests to determine survival potential, top and root growth capacities (TGC, RGC), and field survival and growth (table 2). The greenhouse tests of survival potential and TGC and RGC were started on May 10. The field test was planted on May 11.



TEST	TREATMENT			
	Stress before storage (Jan 12 or Feb 9)	Stress before and after storage	Stress after storage (May 10)	No-stress control
	Number of 10-seedling sets			
Greenhouse survival (May 10 to Jul 9)	3	3	3	3
RGC and TGC (May 10 to Jun 7)	0	0	3	3
Field survival and growth (May 11 to Oct 15)	0	0	10	10

Table 2.--Seedling treatments and sets per lifting date (Jan 12, Feb 9) in tests of a coastal California seed source of Douglas-fir (Gasquet 091.20) grown in the Humboldt Nursery

Stress treatments.--Before cold storage, 6 sets per lifting were dehydrated for 15 minutes at 32° C (90° F), the exposure used in stress tests (Ritchie 1984). The seedlings were individually blotted with toweling to remove surface water, and separately placed on hole-punched stainless steel racks in a thermostatic, vented laboratory convection oven. Immediately after treatment, the seedlings were rehydrated by immersing the roots in tap water at 10° to 15° C (50° to 60° F) for 5 minutes. On May 10, after cold storage, 3 treated and 16 untreated sets per lifting were given the same stress and recovery treatments as applied before storage.

Testing survival potential.--Three sets of 10 seedlings per lifting date and treatment, that is, stressed before cold storage only, before and after storage, after storage only, and not stressed, were planted with a moist mix of fine sandy loam, sand, perlite, and shredded redwood (1:1:1:1) in plastic pots measuring 30 cm in diameter by 30 cm deep (12 x 12 inches). Each set of 10 seedlings was planted in a separate pot, and the pots were randomly arrayed on a table in an air-conditioned greenhouse covered with a 53 percent shade screen. Air temperature was held above 17° C (63° F) at night and below 26° C (78° F) during the day. Day length was extended to 16 hours by operating an overhead bank of mercury-phosphor lamps from 6 to 8 a.m. and 4 to 10 p.m. The seedlings were watered three times weekly.

Survival and shoot growth were determined after 2 months (July 9). After 4 months (September 2), the seedlings were washed free of soil to assess the season's root growth.

Testing growth capacity.--For each lifting, 3 sets of seedlings stressed after storage and 3 sets not stressed were evaluated for top and root growth capacities (TGC, RGC). Each set was divided into 2 groups of 5 seedlings, and each group was planted with the soil mix (1:1:1:1) in a separate stainless steel container measuring 7.5 x 37.5 x 30 cm deep (3 x 15 x 12 inches). The containers were irrigated, drained overnight, weighed, randomized in complete blocks, sealed with rubber stoppers, and immersed to the rim in thermostatically controlled stainless steel water baths located in the greenhouse. The root medium was held at 20° C (68° F), and was watered weekly to full capacity (Jenkinson and Nelson 1978).

New growth of the seedling tops and roots was determined 28 days after planting. Each seedling was evaluated for extension of the leader or longest shoot, new length of all roots elongated 1.5 cm or more, and total number of elongating roots.

Testing field performance.--For each lifting, 10 sets of seedlings stressed after storage and 10 sets not stressed were planted on a cleared south slope of unused land at Humboldt Nursery. The planting layout consisted of 10 replications of a randomized complete block of split plots, with lifting date split for stress treatment. Each of the treatment plots contained a single row of 10 seedlings (a set). The seedlings were planted with a powered soil auger, and were spaced 0.6 m (2 ft) apart in rows that were 1 m (3 ft) apart.

First-year survival, tree height, leader length, and stem diameter were determined 5 months later (October 15), after rains had ended the summer drought. Fourth-year survival and tree height were determined in 1984 (June 26).

Statistical analyses.--The effects of lifting date and stress treatment on seedling performance were assessed by analyses of variance (greenhouse tests, Jennrich and others 1981; field test, Jennrich and Sampson 1981). Means in the greenhouse tests were contrasted by Tukey's method (Steel and Torrie 1960), and in the field test, by Bonferroni's procedure (Miller 1981).

## RESULTS

Survival potential.--Seedlings that were lifted and stressed in January showed a major reduction in greenhouse survival, but the same treatment a month later did not have a significant effect (fig. 1, table 3). Survivals of the seedlings lifted and stressed in January averaged 53 percent. Survival was 100 percent for seedlings that were not stressed, and 97 percent for seedlings stressed only in May, after cold storage. Survival of the seedlings lifted and stressed in February was not significantly different from that of unstressed seedlings and seedlings stressed after storage only. Survivals of seedlings stressed after 4 months or 3 months of cold storage were essentially as high as the survivals of unstressed seedlings.

Table 3.--Analysis of variance for greenhouse survival of Douglas-fir exposed to dehydration stress before or after cold storage or both

Source of variation	Degrees freedom	Mean square	F	Tail prob.
Lifting date, L	1	0.042	0.02	0.887
Stress tmt, S	3	12.486	6.24	.005**
LS	3	10.153	5.08	.012*
Error	16	2.000		

<sup>1</sup> Seedlings of a coastal California seed source (Gasquet 091.20) were lifted at Humboldt Nursery in winter, stored to May 10 at 1° C, and evaluated after 2 months (n = 30, in 10-seedling sets).

Table 4.--Top and root growth capacities (TGC, RGC) and field survival and growth of Douglas-fir exposed or not exposed to dehydration stress after cold storage

Seedling trait	Nursery lifting date				HSD <sup>4</sup>
	Jan 12		Feb 9		
	No stress	Stress	No stress	Stress	
<hr/>					
TGC <sup>2</sup>					
Bud burst, %	91.0	92.5	100.0	96.7	14.6
Leader extension, cm	3.2	2.3	3.3	3.0	1.8
RGC <sup>2</sup>					
Roots elongating, number	115	130	183	159	68.6
Root elongation, cm	110	120	179	130	74.6
Field Performance <sup>3</sup>					
1-yr Survival, %	92	89	97	95	12.0
Tree height, cm	35.0	32.2	31.8	36.4	4.0
Leader length, cm	6.4	6.6	6.4	6.5	1.3
Stem diam, mm	4.7	4.4	4.4	4.6	0.7
4-yr Survival, %	92	86	93	95	13.3
Tree height, cm	90.7	88.4	83.3	86.1	14.6

<sup>1</sup> Seedlings of a coastal California seed source (Gasquet 091.20) were lifted at Humboldt Nursery and stored to May 10 at 1° C.  
<sup>2</sup> Evaluated after 28 days in a greenhouse (n = 30, in 5-seedling sets).  
<sup>3</sup> Evaluated on a nearby coastal site (n = 100, in 10-seedling sets).  
<sup>4</sup> Tukey's or Bonferroni's significant difference at the 5 percent level.



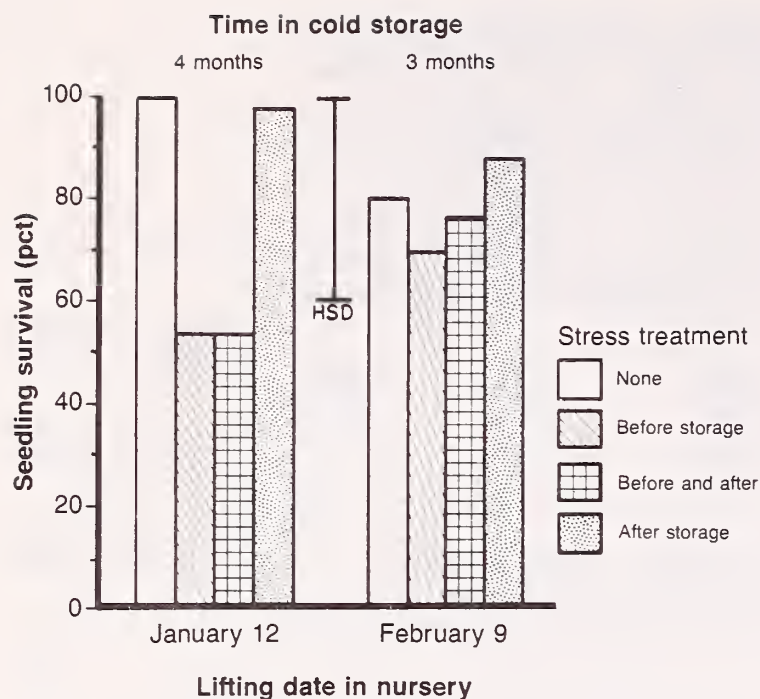


Figure 1.--Lifting date and cold storage affect resistance to dehydration stress in Pacific Douglas-fir. Seedlings of a coastal California seed source (Gasquet 091.20) were lifted at the Humboldt Nursery, stored to May 10 at 1° C, and evaluated after 2 months in a greenhouse. HSD denotes Tukey's honestly significant difference at the 5 percent level (n = 30; see table 3).

Table 5.--Effect of stress test date on estimated survival potentials of 2-0 Douglas-fir grown for the Siskiyou National Forest in southwestern Oregon

Ranger District, seed source code, and test date	Test survival <sup>2</sup>	
	No stress	Stress
<u>Coastal</u> -----Pct-----		
Powers 072.25		
Dec 7	100	47
Mar 8**	100	77
Gold Beach 081.30		
Dec 7	100	10
Feb 8*	100	77
Chetco 082.10		
Dec 7	100	27
Feb 8*	90	23
Chetco 082.20		
Dec 30	100	57
Mar 27**	95	67
<u>Interior</u>		
Illinois Valley 512.40		
Dec 7	100	37
Feb 8*	100	73

<sup>1</sup> Seedlings were lifted at Humboldt Nursery and stored 3 days, 1 month (\*), or 2 months (\*\*) before testing, 1982-83 and 1983-84 (Chetco 082.20).

<sup>2</sup> Two-month survivals from stress tests run by Oregon State University.

The surviving seedlings showed normal shoot growth and substantial root growth. About 20 percent of the seedlings that did not survive flushed the first month, but grew few or no roots.

TGC, RGC, and field performance.--Dehydration stress after cold storage did not significantly affect seedling TGC, RGC, or field performance (table 4). Overall, TGC, RGC, and field survival seemed to be higher for the February than the January lifting, but the differences were not significant and were not reflected in field growth.

## DISCUSSION

Resistance to dehydration stress in Pacific Douglas-fir apparently increases with chilling in the nursery and in cold storage. For the coastal California seed source at Humboldt Nursery, the survival potential of planting stock stressed shortly after lifting increased 21 percent with an additional 28 days of natural cold exposure in late winter (fig. 1). For the same source, the survival potential of stock lifted in January and stressed after cold storage was 97 percent, 44 percent more than for stock stressed at the time of lifting. This increase indicates that cold storage may greatly improve seedling resistance to dehydration damage. The increase depends on the combination of lifting date and storage time, however, because the survival potential of stock lifted in February and stressed after cold storage was only 14 percent more than for stock stressed at lifting.

Survival potential has increased markedly with later stress testing dates for both coastal and interior seed sources of Humboldt planting stock for the Siskiyou National Forest (table 5). Survival potentials of seedlings lifted in January and stored 1 or 2 months were 10 to 67 percent higher than for seedlings tested in December. The exception, a low stress resistance for stored seedlings of Chetco 082.10, may reflect mechanical damage during lifting and sorting in the 1982-83 harvest season.

For any particular seed source, it is likely that the earlier seedlings are lifted and stored within their source lifting window (Jenkinson 1984), the greater will be their increase in resistance to dehydration stress between lifting and spring planting. The California source used in our tests of stress effects has a lifting window that opens in December and closes in March at Humboldt Nursery (fig. 2). Seedlings lifted within their source window have high survival and growth potentials at planting time in spring, regardless of the intervening combination of lifting date and time in storage. Cold storage of seedlings lifted within their source window may promote the development of stress resistance much as it completes the chilling required for dormancy release and rapid shoot growth.



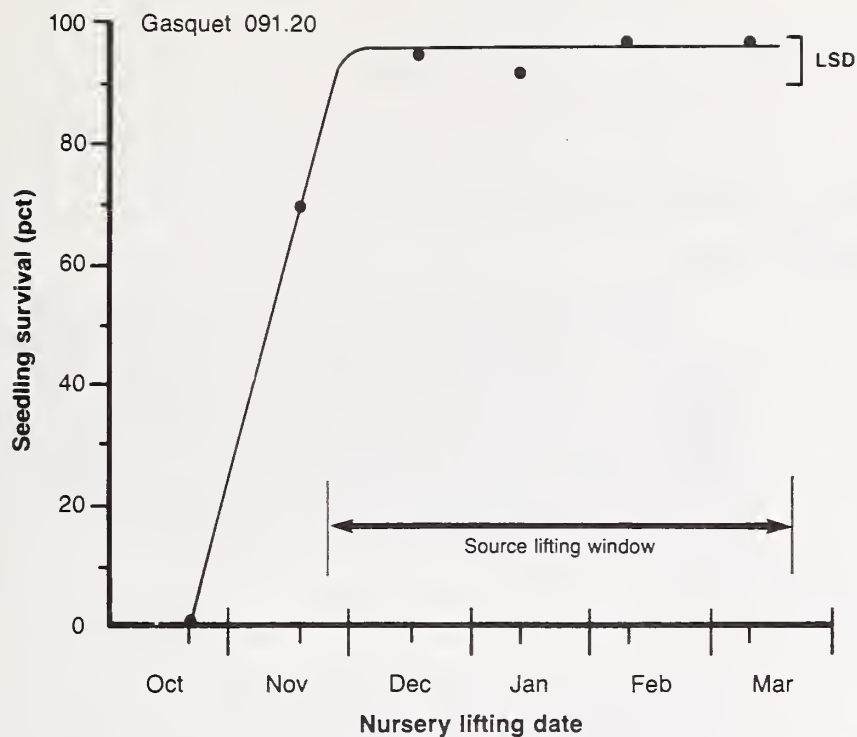


Figure 2.--Effect of lifting date in the Humboldt Nursery on field survival of seedlings from a coastal California seed source of Douglas-fir (Jenkinson 1984). Arrow shows the safe time to lift stock of this source for cold storage and spring planting. LSD denotes least significant difference at the 5 percent level ( $n = 100$ ).

Attempts to predict field survival and growth by testing seedlings 2 or 3 months before their optimum planting times ignore the fact that physiological conditioning continues in the nursery and in cold storage, and ultimately affects stock performance in the field. Seed source and conditioning environment interact to fix the lifting window, TGC, and RGC, and affect both frost and drought resistance. These traits dictate the timing and limit the duration of tests to predict field performance. When sources of Douglas-fir from western Oregon and northern California are properly lifted and stored until spring begins on the planting site, there is barely enough time to squeeze in the 4-week test of RGC (Jenkinson and Nelson 1978) before summer weather closes the planting window (Jenkinson 1980), much less the 2 months required to score a stress test (Ritchie 1984).

RGC at the time of planting has explained 90 to 99 percent of the variation in first-year field survival of almost every source tested (Jenkinson and Nelson 1978, 1983). Because source lifting windows are stable across years (Jenkinson 1984), spring RGC tests of seedlings stored at monthly intervals through one lifting season can be used to refine the nursery's future lifting schedule. On the other hand, results of stress tests can not be extrapolated; they apply only to the particular seedlings tested.

## CONCLUSION

Evidence from our tests and the field suggests that early sampling and stress testing is of little value for predicting field survival of Pacific Douglas-fir. Stress tests to evaluate survival potentials of Douglas-fir from Humboldt Nursery should be done after cold storage, and shortly before spring planting, if they are done at all. For most seed sources, the time is too short to complete a stress test before planting ends.

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SOLARIZATION IN TWO PACIFIC NORTHWEST FOREST NURSERIES //

Sally J. Cooley

**ABSTRACT:** Fumigation and solarization were compared at two Oregon forest nurseries for disease and weed control. Fumigation resulted in significantly reduced levels of both weeds and disease. Solarization, while reducing the number of weeds, did not reduce disease levels. The reasons for ineffective disease control with solarization are discussed.

## INTRODUCTION

Solar heating of soil has been used in recent years to rid large areas of soil of plant pests such as fungi, nematodes, and weed seeds. "Solarization" has been most successful in areas of the world where summer temperatures are relatively high and soils can become correspondingly hot (Ashworth and Gaona 1982; Elad and Chet 1980; Katan 1981; Katan and others 1976; Pullman and others 1979; Pullman and others 1981). Solarization is simple and inexpensive. Clear polyethylene tarping is used to cover the soil and generate high temperatures in the top layers of soil. Pest propagules such as spores, seeds, or eggs are destroyed by lethal high temperatures or disabled by prolonged sublethal temperatures. The following requirements must be met for effective solarization (Katan 1981):

1. Thin transparent polyethylene tarping is necessary. Thin (2 mil) is both cheaper and more effective in heating than thicker polyethylene. Polyethylene has low water vapor permeability; water droplets formed on the inner surface create a greenhouse effect which results in better heating.

2. Tarping must be done during the hottest time of year so that high lethal temperatures are created under the tarp.

3. Application of polyethylene tarping must be made before planting to avoid injury to plants or seeds.

4. Soil must be kept wet during tarping to improve thermal sensitivity of pest propagules and to improve heat conduction in the soil.

5. A long treatment duration is needed (at least 4 weeks in most locations) to adequately heat the soil in cooler, deeper layers. Killing of propagules with prolonged temperatures only a few degrees higher than normal often is superior to a short period of very high temperature.

## METHODS

Solarization trials at the Bend Forest Service Nursery, Bend, Oregon, and at the J. Herbert Stone (JHS) Forest Service Nursery, Central Point, Oregon, were carried out in 1981-1982 and 1983-1984, respectively.

Treatments consisted of fumigation and solarization. Treatment plots were 2,000 square feet (20 feet wide by 100 feet long). Each treatment was replicated four times in a randomized block design. For fumigation treatments, methyl bromide-chloropicrin fumigant was applied at 300 (Bend) to 350 (JHS) pounds per acre in September by a commercial contractor. For solarization treatments, 2 mil clear polyethylene tarps (20 feet x 100 feet) were applied to soil after the soil had been watered well (6 to 8 hours). The tarps were secured at the edges with soil. Tarps were removed after 4 weeks (Bend, July 29 - August 24, 1981) or 6.5 weeks (JHS, June 15 - August 1, 1983). No substance was applied on or into soil in control plots.

Soil temperature and moisture were monitored at four different depths in solarized and check plots during the solarization period.

At JHS, populations of the plant pathogenic fungi, Fusarium spp. and Pythium spp., were monitored in all treatments before and after solarization and fumigation. At Bend, only Fusarium populations were measured.

Ponderosa pine (Bend) and Douglas-fir (JHS) were sown in treated and control areas the spring following treatments. Weed populations were measured prior to sowing and seedling survival was measured periodically after emergence.

## RESULTS

Figure 1 shows temperatures at Bend and JHS, and figure 2 shows percent soil moisture at JHS.

Paper presented at combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Coeur d'Alene, ID, August 14-16, 1984.

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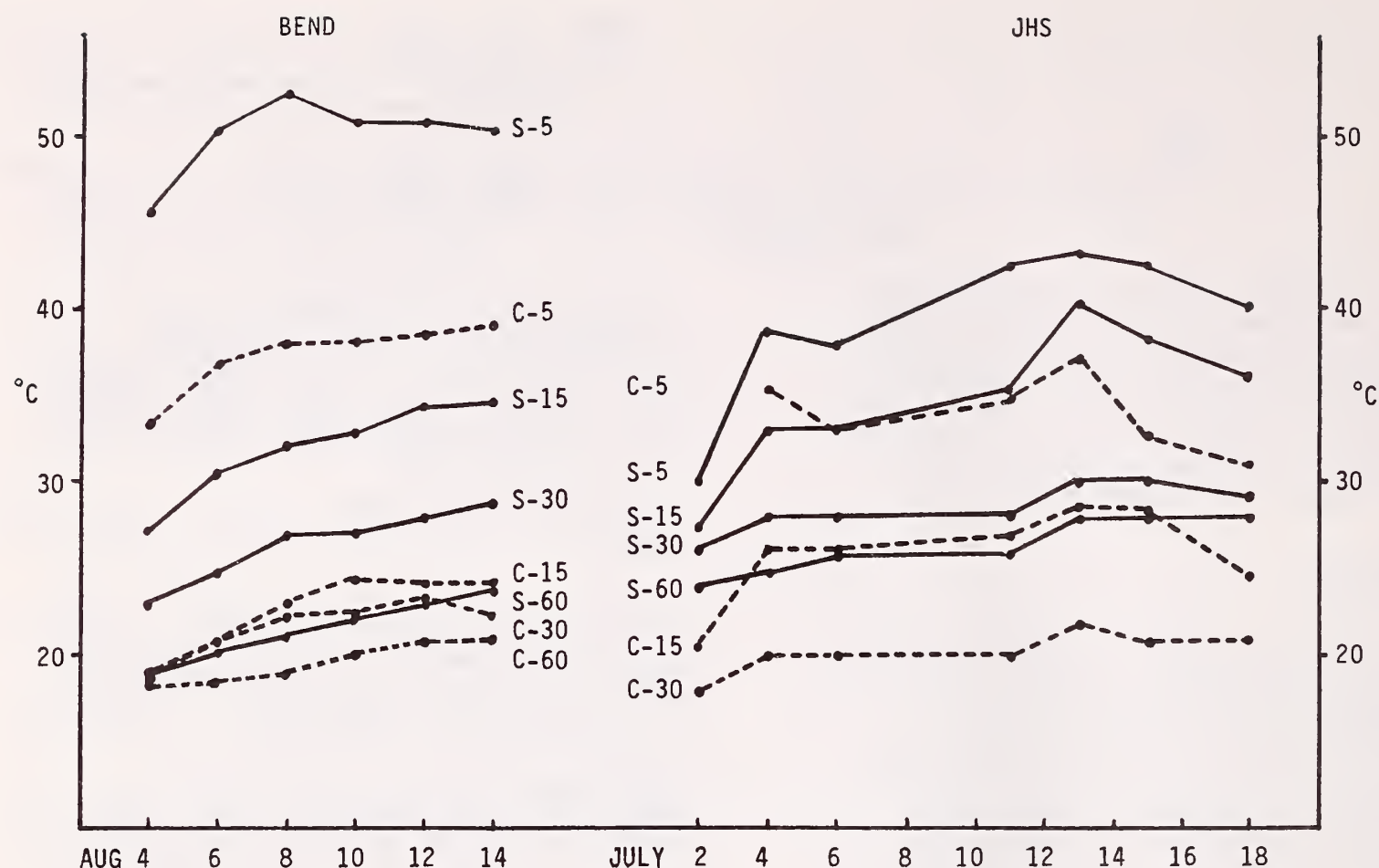


Figure 1.--Soil temperature in untarped (C) and solar tarped (s) plots at the Bend and J. Herbert Stone Nurseries.

At JHS, populations of *Fusarium* were reduced with both fumigation and solarization in soil between 0 and 12 inches deep (table 1). *Fusarium* was completely eradicated by fumigation and reduced significantly (statistically) by solarization. *Fusarium* populations increased in control plots. Similar results were obtained at Bend. *Pythium* populations at JHS were reduced to zero following fumigation; little or no reduction occurred in solar and control plots and there was no significant difference in *Pythium* levels between control and solar treatments (table 2).

Table 1.--Number of *Fusarium* propagules per gram of soil, at two depths, before and after solarization and fumigation. J. Herbert Stone Nursery.

	PRETREATMENT		POSTTREATMENT	
	0 - 6"	6 - 12"	0 - 6"	6 - 12"
Control	2320 a*	1880 a	3400 a	2760 a
Solarization	2640 a	2040 a	920 b	1120 b
Fumigation	2680 a	2600 a	0 b	80 b

\* Means followed by the same letter do not differ significantly according to Student Newman-Keuls Test (P = .05).

Table 2.--Number of *Pythium* propagules per gram of soil, at two depths, before and after solarization and fumigation. J. Herbert Stone Nursery.

	PRETREATMENT		POSTTREATMENT	
	0 - 6"	6 - 12"	0 - 6"	6 - 12"
Control	180 a*	188 a	136 a	146 a
Solarization	184 a	184 a	144 a	128 a
Fumigation	194 a	208 a	0 b	0 b

\* Means followed by the same letter do not differ significantly according to Student Newman Keuls Test (P = .05).

Weed control was best in fumigated areas and poorest in control areas. The number of weeds per unit area is given in table 3.

Table 3.--Number of weeds in fumigated, solarized, and control plots at the Bend and J. Herbert Stone Nurseries.

	Bend (Per Sq. Yd.)	JHS (Per Sq. Yd.)
Control	5.5 a*	36.4 a
Solarization	3.8 ab	5.1 b
Fumigation	1.6 b	4.4 b

\* Means followed by the same letter do not differ significantly according to Student Newman-Keuls Test (P = .05).

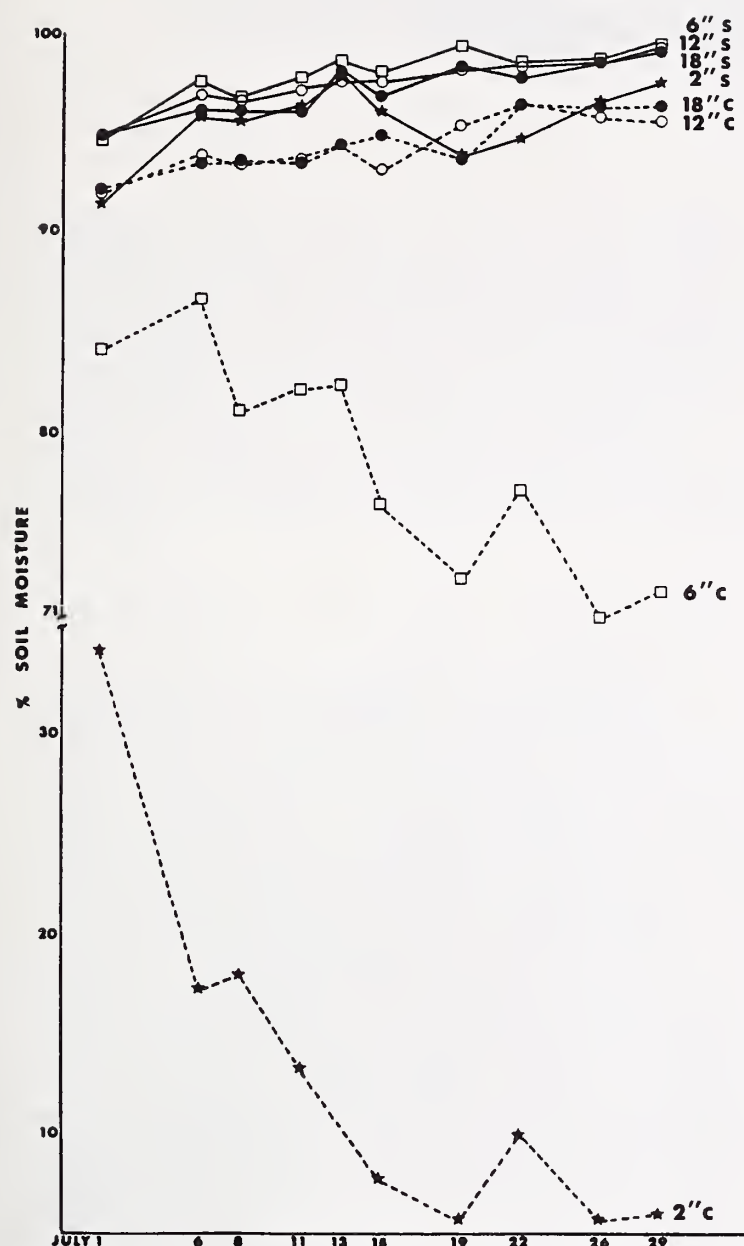


Figure 2.--Soil moisture in untarped (C) and solar tarped (S) plots at J. Herbert Stone Nursery, July 1 - 29, 1983.

Seedling survival after 20 weeks (Bend) and 8 weeks (JHS) is shown in table 4. Survival is best in fumigated areas and similarly poor in solarized and control areas. The average number of seedlings per square foot was four to five times higher in fumigated soil than in solar or control soil at Bend and about one-third higher at JHS.

Table 4.--Percent survival and seedlings per square foot in fumigated, solarized, and control plots at the Bend and J. Herbert Stone Nurseries.

	Bend (10 Weeks)		JHS (14 Weeks)	
	% Survival	Trees/Sq. Ft.	% Survival	Trees/Sq. Ft.
Control	31.9 a*	3	57.7 a	16
Solarization	27.6 a	4	61.4 a	17
Fumigation	69.7 b	15	83.5 b	23

\* Means followed by the same letter do not differ significantly according to Student Newman-Keuls Test ( $P = .05$ ).

## DISCUSSION

Soil temperatures under tarps were raised about 10 degrees higher at 5, 15, and 30 cm depth than soil temperatures in untarped areas. At Bend, temperatures as high as 53° C (126° F) were obtained at 5 cm, 35° C (93° F) at 15 cm, and 29° C (84° F) at 30 cm. Lower temperatures were seen at JHS due to an abnormally cool summer in 1983. Temperature at the shallow depth at Bend was similar to that seen in solarization trials in Israel and California, but temperatures at 15 and 30 cm were somewhat lower than those elsewhere. Katan (1981) reports that temperatures at 20 cm in solarized soils reached 39° to 45° C in various trials in Israel and were similar or higher in California. Apparently temperatures of 40° to 50° C are needed to significantly reduce populations of most soil-borne pathogens; at the lower end of the range, longer exposure times are needed.

At JHS, seedling mortality was caused primarily by *Fusarium oxysporum*, causing root rot and lower stem infections. Pathogens responsible for seedling mortality were not identified at Bend; both *Fusarium* spp. and *Pythium* spp. have been isolated previously from dead or dying seedlings from the Bend Nursery. Numerous reports indicate that soil solarization can effectively control diseases caused by *Fusarium* species on a variety of crops (Katan 1981). Populations of *Pythium* spp. also have been reduced or eliminated after 14 to 58 days of solar tarping (Pullman and others 1981).

At Bend, the number of weeds in solarized plots was intermediary between control and fumigated plots. At JHS, both solarized and fumigated areas had significantly fewer weeds than control areas. Katan (1981) reports good control of most annual and many perennial weeds with solarization; control of grasses is more variable.



Several factors may have contributed to the poor results seen in these two solarization trials:

1. Poor reduction of pathogen populations during solarization due to inadequate temperatures in the lower soil layers. This could be corrected or improved by an extended tarping period. Temperatures achieved in solarized soil will be expected to vary from year to year, as they are very dependent on weather at the time of solarization.

2. Buildup of residual pathogenic fungi in solarized soil in the period between solarization and sowing the following year. Presence of organic matter from cover or green manure crops in the soil may provide an adequate food base for buildup of pathogenic fungi (e.g., *Fusarium*) that are able to exist as saprophytes in the absence of host plants.

3. Inadequate soil moisture during the solarization period (Bend only) due to very sandy, porous soil. Pest propagules, such as seeds and spores, are much more resistant to high temperatures in dry rather than wet environments (i.e., moisture induces germination, imbibition of water, etc. resulting in increased sensitivity to heat).

Although solarization proved to be ineffective in controlling diseases in two Pacific Northwest forest nurseries, given the necessary climate and the appropriate management of solarized soil, solarization may be effective in some forest nurseries.

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## FLUID DRILLING (GEL SEEDING) FOR WILDLAND PLANTINGS:

## SOME PRELIMINARY STUDIES //

D. Terrance Booth

**ABSTRACT:** Fluid drilling and the associated technique for cold storage of stratified seed were evaluated for their potential in establishing woody plants on range, mined, and forest land. Significantly more seedlings resulted from fluid drilling in spring than from drilling dry seed in fall or spring. Fluid drilling is recommended for further research to develop it as a cultural method for wildlands.

## INTRODUCTION

Fluid drilling is a technique for planting imbibed seed or germinants. The seed is planted while suspended in a gel, which protects it and carries it into the soil (Currah and others 1974, Biddington and others 1975, Taylor 1977). Control of seed environment during pre-planting incubation, and separation of germinated from nongerminated seed using a sucrose solution (Taylor and others 1978) are management options made possible by this planting method. If needed, cold storage can be used to arrest seedling development until planting takes place (Wurr and others 1981, Finch-Savage 1981). These cultural methods are improving plant spacing in nursery beds and reducing the number of empty containers in the greenhouse (Searcy and Roth 1981, Skeates 1982). Fluid drilling is also a means of planting fluffy or hairy disseminules such as winterfat (Eurotia lanata) fruits, (Booth 1984) which tend to plug other types of seed drills.

Most commercially available fluid drills use the squeezing action of peristaltic pumps to extrude the gel. Ghatte and others (1981) designed, built, and tested compressed air and peristaltic pump planters. They found the compressed air system to be superior.

Paper presented at combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Coeur d'Alene, ID. August 14-16, 1984.

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Fluid drilling is now used to plant vegetable and nursery crops, but its potential for direct seeding shrubs and trees on range, mined, and forest land is not developed. Establishing desirable shrubs on rangeland could increase quantity and quality of available forage (Van Epps and McKell 1977, Rumbaugh and others 1982). The restoration of native shrubs and trees on mined land is prerequisite to successful reclamation and is often mandated by law. Western reforestation, largely dependent upon transplants, would benefit from low-cost cultural methods on land with low productivity. Land managers need inexpensive methods for establishing woody plants over large areas. The development of such methods is the objective of seeding research at Cheyenne, where two aspects of fluid drilling have received preliminary study. They are the cold storage of shrub seed after stratification and fluid drilling trials using a variety of species.

## COLD STORAGE

Storage for fifteen days at 34°F (1°C) caused no loss of seedling vigor in germinated carrot (Daucus carota) and parsnip (Pastinaca sativa) seeds (Finch-Savage 1981). However, storage of pregerminated lettuce (Lactuca sativa) seeds at 32 or 36°F (0 or 2°C) did not prevent radicle elongation, and an increase in radicle length from 0.3 to 0.8 in. (0.8 to 2.0 mm) was found to delay emergence (Wurr and others 1981).

The potential for holding stratified shrub seed in cold storage was evaluated by measuring the effect of storage time and storage temperature on the germination and seedling vigor of big sagebrush, (Artemisia tridentata), winterfat, and bitterbrush (Purshia tridentata).

Stratified seeds were stored and cultured on inclined acrylic-plastic germination plates (Jones and Cobb 1963) placed in enameled pan reservoirs. Big sagebrush seed was stratified for 10 days at 36°F (2°C) and bitterbrush for 14 days at 36°F (2°C), while winterfat was soaked for 2 days in deionized water at 32°F (0°C). A large circulating, refrigerated water bath was used to store stratified seed at 41, 32, and 23°F (5, 0 and -5°C) for 0, 2 and 4 weeks. Temperature variation was  $\pm 2.7^\circ\text{F}$  (1.5°C).



After storage the seeds were germinated and grown in reach-in type growth chambers maintained at 70°F (21°C) for 8 hours with light (all species) and without light for 16 hours at 50°F (10°C) for sagebrush and bitterbrush and 40°F (4.4°C) for winterfat.

One hundred seeds were used in each experimental unit and each unit was replicated four times. Species were randomly assigned to pans within blocks. The 2-week storage treatment (for each species) was added to the assigned pan at the appropriate time. Stratification of controls (0 weeks of storage) was timed to coincide with the end of storage. The controls were not subjected to treatment temperature, therefore in the analysis of variance, the means of all control within species were pooled. Equipment limitations forced the study to be conducted as six 4-week runs, with each run having two replications at test temperature. The sequence of temperature treatments was randomized. Germination and hypocotyl lengths were recorded after stratification, after storage, and nine times during the 28 days of incubation. Seedlings were removed from germination plates when hypocotyl length was first observed to exceed 1.6 in. (40 mm). This was done to avoid measuring seedling roots which grew into the unaerated water at the bottom of the germination plate.

Big sagebrush had no loss of germination or vigor with any treatment. The 28-day germination for all treatments was within 3.25 percentage points of the mean of the control (93 percent). However, after 2 days incubation, the 4 week, 32°F (0°C)-treatment had 80 percent germination compared to 53 percent for the control. The average growth rate for this treatment was 0.049 in/day (1.24 mm/day) as compared to 0.035 in/day (0.89 mm/day) for the check. These differences are not significant at the 5 percent level of probability and there was no significant storage time by temperature interaction. However, the shallow seeding depth which big sagebrush requires makes rapid germination and initial growth critical to plant establishment. Therefore, the above trend may merit further study.

Winterfat germination (percent of total) during 2 weeks of storage was 91 percent at 41°F (5°C) and 65 percent at 32°F (0°C), and after 4 weeks of storage was 99 and 86 percent, respectively. Winterfat germination (actual) was significantly reduced at 23°F (-5°C) storage temperature and by longer storage time (fig. 1). Therefore, winterfat storage must be at a temperature below 32°F (0°C) and for the minimum time possible. Average growth rate of seedlings from the 23°F (-5°C) treatment did not differ significantly from the control. Other comparisons were not made because of the high percentage of germination during storage.

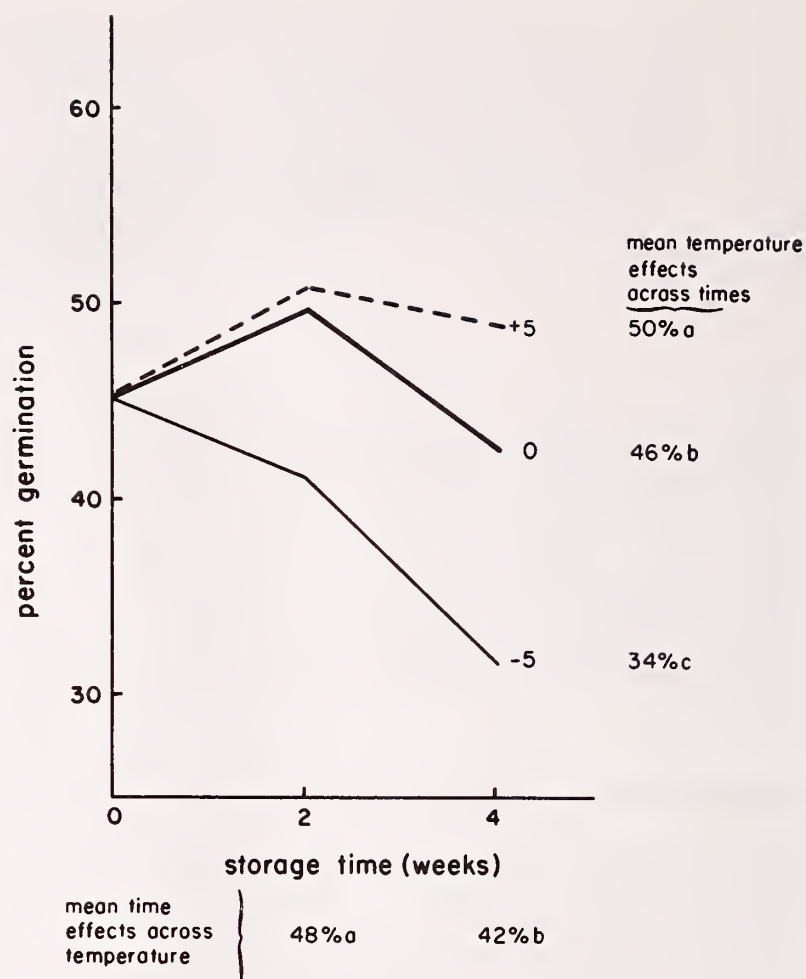


Figure 1.-- Winterfat germination (storage + incubation) as affected by storage time and temperature in degrees C (5°C = 41°F, 0°C = 32°F, -5°C = 23°F). Means followed by the same letter are not significantly different at .05 level of probability.

The bitterbrush stratification period used was 1 week short of the time recommended by Young and Evans (1976) for complete stratification at that temperature. They indicate that holding fully stratified seed at the stratifying temperature will cause reduced germination.

As expected, stratifying for only 2 weeks reduced the germination of the check, but there was no loss of germination with storage time. Germination means of temperature treatments across storage times were all different from each other, except that the control was not different from the 23 F (-5°C) treatment (fig. 2). The growth rate of seedlings stored at 41 F (5°C) was significantly better than growth rates of seedlings from other treatments. Cold storage of germinating shrub seed is feasible as a means of holding the seed in the required stage of development. However, the optimum storage temperature and storage time varies with the species and with the conditions of seed stratification.

#### FLUID DRILLING

One of the problems associated with the establishment of shrubs on the High Plains is

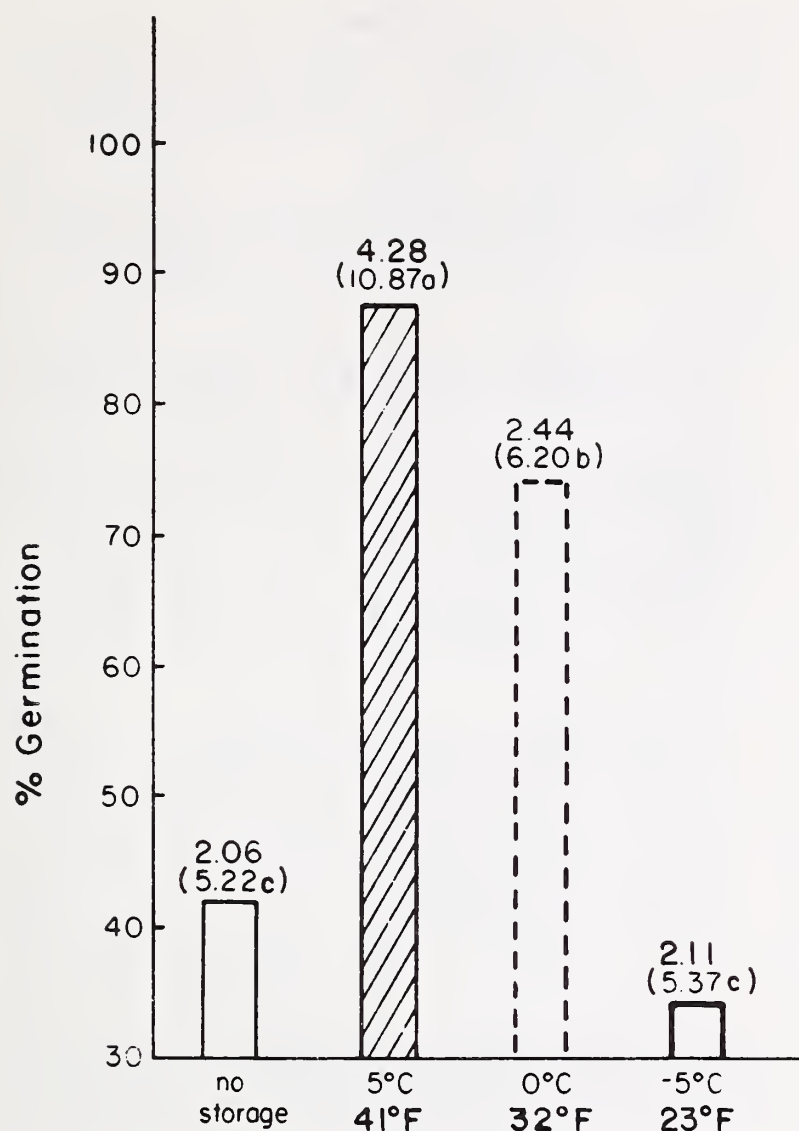


Figure 2.-- Germination and subsequent hypocotyl growth rate in inches/day (mm/day) of bitterbrush as affected by storage temperature averaged over time. Growth rate means followed by the same letter are not significantly different at the .05 level of probability.

the erratic nature of the climate. Conditions necessary for germination of dormant shrub seed do not occur every winter. This problem might be overcome by stratification of the seed followed by fluid drilling in the spring. To test this idea, fall and spring dry seedlings and a spring fluid seeding were made in 1982-1983 and 1983-1984 using 14 species (table 1). Seedlings were made as 100 ft. (30.5 m) rows using 6 seeds per ft. (20 seeds per m). A random design with three replications was used among all treatments of all species. Comparison between species was not an objective of the study. Stratification times generally follow those recommended in Agriculture Handbook No. 450 (Schopmeyer 1974). A fluid drill for seeding research plots was constructed by mounting a 15 in. (38 cm) funnel on a hand drill. Gel flowed by gravity through a 0.75 in. (1.9 cm) inside diameter Tygon tube into a furrow formed by a double disk opener. The carrier gel consisted of a 1:250 mix of SGP (Henkel Corporation, Minneapolis, MN) and distilled water. Gel was dispersed at about

.8 in.<sup>3</sup> per ft. (42 cm<sup>3</sup>/m) of row. The 1983-84 seedlings were made at three different sites, one of which was on mined land. The weather prevented the fall 1983 planting at two sites, therefore 1983-1984 data compare only spring seeding and fluid drilling.

Both years provided cold-moist seedbed conditions in the fall with a dry period in January and February followed by above average spring precipitation and below average temperatures. The exception was May, 1984, which had below normal precipitation and above normal temperatures.

Fluid drilling resulted in significantly more seedlings than did the spring or fall dry seedlings (table 2). Inadequate stratification of spring dry-drilled seed probably accounts for the lower establishment in that treatment as compared to the fall dry drilled seed. Only mountain mahogany (*Cercocarpus montanus*) and American plum (*Prunus Americana*) had significantly more seedlings from fluid drilling than from other treatments in 1983 (table 1).

#### CONCLUSIONS

These plantings were exploratory and designed to gain experience in direct seeding shrubs and trees by fluid drilling. Fluid drilling (and associated cold storage techniques) are an avenue for progress in the culture of woody plants on wildlands. This conclusion is based on the encouraging results of these studies and on the fact that fluid drilling increases man's control of the seed and its environment, but retains the capability for extensive, low-cost dispersal.

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Table 1.--1983 Mean seedling emergence per row by species and planting method<sup>1</sup>

Species	Stratification Time In Days	Germ <sup>2</sup>	Fall Dry Drilled	Spring Dry Drilled	Spring Fluid Drilled
<u>Amelanchier alnifolia</u> (Serviceberry)	160	X	24.7a	0b	4.3b
<u>Caragana arborescens</u> (Siberian peashrub)	40		7.7b	136.3a	18.3b
<u>Cercocarpus montanus</u> (Mountain mahogany)	30		4.0b	0.7b	21.0a
<u>Crataegus ambigua</u> (Hawthorn)	140		0a	0a	0a
<u>Elaeagnus angustifolia</u> (Russian olive)	90		228.0a	21.7c	110.b
<u>Malus baccata</u> (Crab apple)	30		1.7a	9.3a	6.0a
<u>Pinus ponderosa</u> (Ponderosa pine)	60		13.3b	37.0ab	56.7a
<u>Prunus americana</u> (American plum)	150	X	12.3b	0b	110.0a
<u>Prunus virginiana</u> (Choke cherry)	160	X	23.7a	0c	14.0b
<u>Purshia tridentata</u> (Bitterbrush)	14	X	90.0a	98.3a	189.7a
<u>Rhus trilobata</u> (Skunkbush sumac)	60	X	39.7ab	2.0b	79.3a
<u>Ribes aureum</u> (Golden currant)	60	X	38.3a	7.7b	2.7b
<u>Rosa woodsii</u> (Woods rose)	30		5.3a	0a	0a
<u>Sheperdia argentea</u> (Silver buffaloberry)	90	X	38.0a	0.3b	28.0ab
	Mean		37.6	22.4	45.7

<sup>1</sup>Means, with in each species, followed by the same letter are not significantly different at the .05 percent level of probability.

<sup>2</sup>Species germinating during lab stratification.

Table 2.--Effects of seeding method on seedling numbers and their percent of the total

Year & Method	Number seedlings (all species)	Percent of total population (Z.05) <sup>1</sup>
1982-83		
Spring	940	20-22
Fall	1579	34-37
Fluid drill	1920	42-45
Total	4439	
1983-1984		
Spring	418	31-36
Fluid drill	841	64-69
Total	1259	

<sup>1</sup>Confidence intervals were calculated by assuming a binomial distribution (Steel and Torrie 1960).

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NEW SEEDING AND LIFTING CONCEPTS

IN BRITISH COLUMBIA //

Ralph F. Huber

ABSTRACT: All bareroot seed for Douglas-fir and lodgepole pine was precision-sown in 1984 at nurseries in British Columbia. Lifting was done with side-delivery systems on lifters into field bins on a trailer instead of tote boxes.

#### INTRODUCTION

Field foresters want seedlings that will have better survival and free growth. Research has shown that by lowering densities we can produce seedlings that will give better survival and growth in the plantation. In order to lower densities and achieve regular spacing in the seedbed a more efficient seeder than those previously used was a necessity. In 1982 a Summit precision seeder was purchased and in 1984 a Miniair precision seeder was acquired.

In 1983 the recession and restraints on FTE's indicated we needed to look at some of our nursery practices. One practice on which we could save manpower was field lifting. Tote boxes were being used in the field to retrieve seedlings behind both the Grayco and Fobro lifters. In place of tote boxes we have switched to field bins on a trailer. To fill the bins with seedlings, we installed a side delivery system on the Grayco lifters and purchased seedling combines to follow the Fobro. Switching to this type of system will save up to 12 employees per lifting shift.

#### SEEDING

Prior to 1984 all bareroot seeding was done with either a Wind River seeder or Oyard. Seeding with these machines resulted in uneven distribution of seed, thus giving clumps of seedlings in the row, resulting in poor growth of some seedlings. The Oyard did a better job of seed distribution, but still lacked in precision distribution. In 1982 limited experimental precision seeding was started, some operational seeding began in 1983, and

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all Douglas-fir and lodgepole pine were precision-sown in 1984.

#### PRECISION SEEDERS

##### Summit Precision Seeder

Manufactured by Summit Engineering of Rotorua, New Zealand, the Summit Seeder originally was a unit designed to form beds, pack seed, and cover seed, in one operation. We have never used the bed-shaping capability of the machine. In the future, this seeder will be available in three models--seeder with a three-point hitch only, seeder with fertilizer injector, or seeder with bed-forming capability.

The vacuum sowing head on the Summit is one solid drum with seven rows of orifices corresponding to each row of nursery bed. Originally, the sowing drum was designed to handle large-seeded species such as Douglas-fir or ponderosa pine. They have since developed a drum which will handle small-seeded species such as spruce or lodgepole pine, as well as large-seeded species.

Spacing in the row by the Summit seeder is dictated by an arrangement of two sprockets. Sprockets with a different number of teeth (14 to 69) are used to give a spacing of 1.0 cm to 13.0 cm. Table 1 gives an example of the spacing the seeder is capable of.

When seeding with the Summit, speed of travel is very important. The recommended travel speed is 60 feet (18 meters) per minute. Accuracy of the machine decreases as travel speed increases.

##### Miniair Precision Seeder

Manufactured by H. Fahse and Co. of Duren, West Germany, the Miniair is used extensively for agricultural purposes in Europe. We use this machine for sowing lodgepole pine and a limited amount of white spruce on an experimental basis.

In comparison to the Summit, which has one vacuum drum for sowing seven rows, the Miniair has seven individual sowing heads. Each sowing head has a vacuum disc with orifices for picking up seed. The Miniair will work only with smaller-seeded species.

Spacing in the row by the Miniair seeder is dictated by an arrangement of four gears. By interchanging the gears the machine is capable of achieving spacing from 0.6 cm to 6.0 cm. Table 2 gives an example of the spacing the seeder is capable of. Interseed distances greater than those in table 2 can be achieved by using a smaller drive sprocket.

As with the Summit Seeder, speed of travel is important. The factory recommends that ground speed should be such that the seed can be visible on the rotating seed pickup discs. Our experience is that this is approximately 65 feet (20 meters) per minute. Accuracy of the machine will decrease with increased speed of travel.

Table 1.--Spacing capability of the Summit Precision Seeder showing the number of seeds laid down in seven rows per bed meter

Interseed spacing (cm)	Seeds per bed meter
1.00	700
1.26	555
1.53	457
1.75	400
2.00	350
2.27	308
2.47	283
2.75	254
3.07	228
3.30	212
3.46	202
3.79	184
4.01	174
4.21	166
4.45	157
4.71	149
4.95	141
5.20	135
etc.	

Table 2.--Spacing capability of the Miniair Precision Seeder showing the number of seeds laid down in seven rows per meter

Interseed spacing (cm)	Seeds per bed meter
0.6	1 167
0.8	875
0.9	778
1.1	636
1.3	538
1.5	467
1.8	389
1.9	368
2.3	304
2.7	289
2.9	241
3.0	233
3.5	200
3.9	179
4.6	152
6.0	117

## PRECISION SOWING

Before establishing precision sowing rules one must establish how many seedlings per bed meter one wants to ship and how many seedlings are required to reach this shippable number. In British Columbia, we looked at our sowing rules and worked from that point to establish new rules. Tables 3 and 4 give a comparison for coastal Douglas-fir and lodgepole pine, respectively, for old and new sowing rules. Note that amount of viable seed sown for Douglas-fir per bed meter is approximately 50 percent and lodgepole pine 17 percent of old sowing rules.

Because the number of viable seed per meter sown is down, the expected recovery per meter must also be down. Tables 3 and 4 show the projected recovery. You will have to take into account that precision sowing will take more bed meters. In our case, Douglas-fir takes 80 percent more bed meters, while lodgepole pine takes 15 percent.

Once you have established how many viable seeds per bed meter you want, you can establish spacing. Tables 5 and 6 show the spacing we use in our nurseries. You will notice that we broke viability percentage into blocks of 10. This was done to eliminate gear changes. You will note (table 5) that we keep an average of approximately 200 viable seeds per bed meter for all spacings in Douglas-fir. The spacing is figured out by dividing the number of centimeters per row times the number of rows per meter by the number of seeds to be laid down. Consideration must be given to the total number of seeds, not only the viable seeds.

The numbers presented here are our best guess and until such time as we gather more historical data, will probably not be changed. We feel we might be conservative in our numbers.

At this point, I remind you that what works for one nursery may not work at another location.

## ADVANTAGES AND DISADVANTAGES OF PRECISION SEEDING

### Advantages

- Greater dry weight
- Greater root collar diameter
- Fewer culls, therefore less spent on grading
- Better survival and free growth after planting
- Larger number of seedlings from a given amount of seed

### Disadvantages

- More seedbed, therefore greater cost for fertilizers, hand weeding, and lifting
- More packages required
- Greater trucking costs



Table 3.--Projected recovery of plantable seedlings per bed meter by viable seed sown--  
Douglas-fir (Coastal)

Nursery	Viable seed per meter sown		Projected recovery		Recovery factor %		Recovery increase %
	Old	New	Old	New	Old	New	
CRN	395	200	215	120	54	60	11
GTN	490	240	215	120	44	50	14
CHW	490	240	215	120	44	50	14

Table 4.--Projected recovery of plantable seedlings per bed meter by viable seed sown--  
lodgepole pine

GTN	360	300	230	200	64	67	5
SKM	360	300	230	200	64	67	5
RRK	395	300	230	200	58	67	15
SUR	360	300	230	200	64	67	5
TLK	360	300	230	200	64	67	5

Table 5.--Sowing rules for precision sowing coastal Douglas-fir at Campbell River Nursery with  
Summit precision seeder

Viability	Interseed distance	Seed per meter sown	Viable seed per meter	Recovery per meter	Recovery factor %
91 - 100	3.30	212	193 - 192	120	56 - 62
81 - 90	2.81	249	201 - 224	120	54 - 60
71 - 80	2.81	262	186 - 200	120	60 - 64
61 - 70	2.31	303	184 - 212	120	54 - 63
51 - 60	1.87	374	190 - 224	120	54 - 63
50	*	varies	250	120	48

\*Sown with Wind River Seeder

Table 6.--Sowing rules for precision sowing lodgepine pine at all nurseries (spring 1984) with  
Summit precision seeder

Nursery	Seed viability	Interseed distance	Seeds per meter sown	Viable Seed per meter sown	Recovery per meter	Recovery factor %
CRN	91 - 100	2.23	314	286 - 314	200	64 - 70
GTN	81 - 90	1.99	351	284 - 316	200	63 - 70
SKM	71 - 80	1.76	397	282 - 318	200	63 - 71
SRY	61 - 70	1.53	458	279 - 321	200	62 - 72
	51 - 60	1.30	540	275 - 324	200	62 - 73
	41 - 50	1.06	659	270 - 329	200	61 - 74
	40	*	Varies	360	230	64
TLK	-	*	Varies	360	230	64

\*Sown with Wind River Seeder

## LIFTING

Up until 1983, all lifting was done using either a Grayco or Fobro lifter. Seedlings, in the case of the Grayco, were deposited into tote boxes at the rear of the machine and then put onto a trailer travelling alongside. With the Fobro lifter we had from 12 to 16 people picking up seedlings from the seedbed, placing them into tote boxes and then onto a trailer. Lifting was one area that we zeroed-in on to save manpower. We installed a side delivery system on the rear of the Grayco to transport seedlings up into bins on the trailer. In cooperation with Fobro, a combine was developed to pick seedlings up off the seedbed and transport them by conveyors into bins on a trailer. We switched from tote boxes to bins in this change of lifting practice.

### Grayco Lifter

Manufactured by Evergreen Tree Seedling Harvesters, Heidelberg, Ontario, Canada, our Grayco lifters originally were equipped with personnel carriers. The personnel carriers saw limited use in our operations. When the idea of a side delivery and bin system came up, the first place we looked for parts for fabrication was the personnel carriers. All parts for the side deliveries--chains, hydraulics, etc.--were cannibalized from the personnel carrier. This saved us a considerable amount of money; by using the side delivery we do away with seven people in the field.

### Fobro Lifter

This machine is manufactured by Baertschi & Co. Ltd. of Hueswil, Switzerland. For the past few years, we have been using Fobro lifters in a number of our nurseries. Up until 1983, we had from 12 to 16 people following the Fobro to pick up seedlings from the seedbed, place them in tote boxes, and stack them onto a trailer. In 1983, we purchased our first Fobro combine to pick up seedlings off the seedbed and transport them up and over to a trailer with field bins. Since our first model was purchased, we have made numerous modifications to the combine. The major modifications were: using potato digger chains instead of belts, which eliminated a lot of soil in the bins; a lift on the side delivery system so tractors can pass under when changing trailers.

The combine can save you up to 15 people in the field lifting operation. Depending on production of the nursery, a combine will pay for itself in short order. During our 1984-85 lift we will have four combines in operation.



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## DESIGNING THE BEND NURSERY TREE INVENTORY SYSTEM

Mahlon Hale

**ABSTRACT:** In 1979 the Bend Nursery recognized a serious problem with its tree inventory projections. As a result, a review was made of seedling population characteristics and the inventory procedure was significantly revised. The new inventory relied heavily on statistical analysis and seedling size measurements. The new system has significantly increased the reliability of the inventory as well as providing needed information about seed lot sizes.

### INTRODUCTION

For a number of years the Bend Pine Nursery had been using an inventory system based on systematic plot sampling of its tree lots using more or less typical nursery inventory procedures (Stoeckeler 1957). The original system, based on 1' x 4' (30.48-cm x 121.92-cm) rectangular sample plots, was calculated by hand. It did not use statistical evaluations. Adjustments to the inventory were based on past experience for species, seed bed density, and typical grading and cull rates.

The number of trees actually graded and packed would vary as much as  $\pm 25$  percent to  $\pm 50$  percent per tree lot with an overall trend for all production to underrun appreciably. It was apparent that this inventory system was not reliable.

### EVALUATING PAST INVENTORY DATA

In 1979, the Nursery began analyzing its population characteristics in order to design a new inventory system that would more accurately predict the trees available for shipment.

### Population Characteristics

The Bend Nursery typically grows 5MM to 7MM shippable trees. Because of harsh, cold winters and the possibility for frost to occur in any

month of the growing season, the Nursery can successfully grow only two conifer tree species--ponderosa pine, (*Pinus ponderosa* [Laws]), and lodgepole pine, (*Pinus contorta* [Doug1.]).

A review of past Nursery inventory records revealed that tree lots were frequently variable in size, ranging from 1,000 trees to 1.25MM trees. The following bar graph (fig. 1) shows the skewedness of population sizes and frequency.

Trees were commonly sown 7 rows per 4-foot (1.2-meter) wide beds. Seedling density commonly ranged from 10 to 45 live trees per square foot (0.092 sq. meters). Seedling uniformity within seed beds and within drill rows fluctuated noticeably.

Samples of seedling lots revealed that tree count coefficients of variation ranged from 18 percent to 30 percent with 24 percent being about average. Sampling trials revealed that coefficient of variation could be reduced generally by reducing rectangular plot sizes from 1'x4' (30.48-cm x 121.92-cm) to 1/2' x 4' (15.24-cm x 121.92-cm).

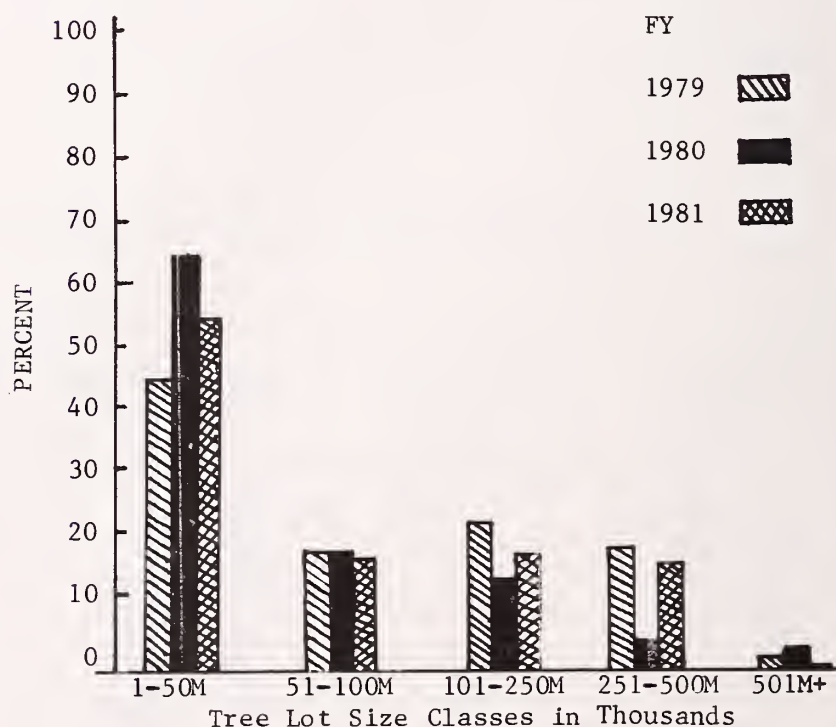


Figure 1.--Percentage of tree lots by size classes

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Tree caliper and height size measurement samples were being taken on every sixth tree counted. Statistical analysis showed resultant accuracies to commonly range from 3 percent to 10 percent at 1 Standard Deviation, which was considered adequate.

#### DESIGNING THE INVENTORY SYSTEM

Ranger districts needed more information about the percentage of trees by size classes in order to match the stock to planting sites and to recommend changes in grading specifications. Also the Nursery needed this information to predict the number of trees to be shipped. Through trial and error, the Nursery designed a tree inventory size-class tally form to record this information. (Refer to the tree inventory tally forms in the Appendix for details.) Also, the size class measurements could be used to predict net shippable trees.

#### Selecting Inventory Reliability and Accuracy Standards

Experience with previous inventory design problems showed that trial inventories based on 1 Standard Deviation would be too weak (67 chances out of 100 for success) while at 2 Standard Deviations (95 chances out of 100 for success) they would be too labor intensive for a large scale operation. Therefore, 1.6 Standard Deviations (89 chances out of 100 for success) was selected for the initial trial. Next, accuracy standards were selected based on a series of trial-and-error calculations comparing the approximate cost to inventory to probable impact of tree volume errors to district planting programs. The following accuracy standards were used:

#### Inventor Target Accuracy Standards

<u>Tree Lot Size</u>	<u>Min. Accuracy Standard</u>
1-50M	10%
51-250M	7%
251-500M	5%
501-1MM	4%
1MM plus	3%

Inventory sampling intensities were calculated based on the standard sampling formula (Dilworth 1955).

$$N = \frac{n t^2 c^2}{n A^2 + t^2 c^2}$$

#### Inventory Procedures

Rectangular plots of 1/2' x 4' (30.48-cm x 121.92-cm) were systematically distributed throughout the tree lot. Live trees were counted and every sixth tree per plot was measured for caliper and height. No grading was

done. Crews were instructed to write narrative statements on the inventory form to alert the Nursery personnel to any unusual tree lot characteristic.

Refer to the inventory procedural instructions in the Appendix for additional details.

#### Computational Procedures

The net shippable volume per tree lot was derived from the gross volume computations times a shipping factor adjustment. The following formulas were used:

#### Gross volume.--

$$\frac{\text{Total Trees on Plots}}{\text{Total Plots}} \times \text{No. Plots/BF} \times \text{Footage (meters) sown}$$

#### Shipping factor.--(Adjustment of gross volume to net volume)--

1. Percentage of trees currently shippable from size class measurement array. See Figure 2.

TREE LOT # 14-8352  
PERCENT OF GROSS TREES BY DIAMETER AND HEIGHT

SIZE CLASSES *	caliper in mm					
* ht. cm. (in) *	1.2	2 1/2	3	3 1/2	4-6	7+
*****	*****	*****	*****	*****	*****	*****
* 1-6 (<2 1/2)*	0.0	0.0	0.0	0.4	0.8	0.0
*****	*****	*****	*****	*****	*****	*****
* 7-9 (3-4)	0.4	0.0	1.2	1.2	5.2	0.0
*****	*****	*****	*****	*****	*****	*****
* 10-20 (4-8)	0.0	0.0	2.8	2.0	78.3	1.6
*****	*****	*****	*****	*****	*****	*****
* 21+ (8+)	0.0	0.0	0.0	0.0	5.6	0.4
*****	*****	*****	*****	*****	*****	*****

Figure 2.--Size class measurement array

2. Ingrowth allowance from size class measurement array for undersized trees.

3. Cull factor. Experienced culling rates for cull roots, top damage, disease, etc.

$$\text{Shipping Factor} = [(1)+(2)] \times (3)$$

#### Net shippable trees.--Gross volume x shipping factor

For actual computer calculations and printout refer to Appendix.

#### MONITORING THE INVENTORY RESULTS

During the trial inventory, each tree lot was analyzed statistically to assure it met prescribed accuracy standards. If minimum accuracy was not achieved, additional plots were taken.



Occasionally on problem tree lots, it was necessary to increase plot size to 1' x 4' (30.48-cm x 121.92-cm) to overcome coefficient of variation problems. In unusual cases where mortality created extreme coefficient of variation, populations were stratified and resampled to improve the accuracy.

### Initial Findings

The initial inventory showed a number of significant operational problems, such as:

1. Bed footage measurements contained errors. The inventory crew was instructed to measure accurately between plots and determine the correct bed footage for each tree lot.

2. Plot sampling intensities were initially excessive for the accuracy needed. Based on the 1-0 age inventory results, the 2-0 age inventory sampling intensity was reduced. The Proposed sampling intensity for 1-0 age trees is as follows:

Size of Tree Lot	Target Accuracy	Recommended Percent Sample
0.5-10M	10%	10.0
11-30M	7%	4.0
31-100M	5%	2.0
101-250M	4%	1.5
251-500M	3%	1.5
501-1MM	2%	1.0
1.1 + MM	1%	1.0

3. Tree size measurement sampling procedures were too slow. The procedure was revised from sampling every sixth tree to measuring the first and last tree in each drill row within the plot (typically 14 trees per plot for seven-row beds). Inventory time was speeded up and accuracy was increased.

### Reliability Trend

The following graph (fig. 3) shows the reliability trend for the Bend Nursery inventory system.

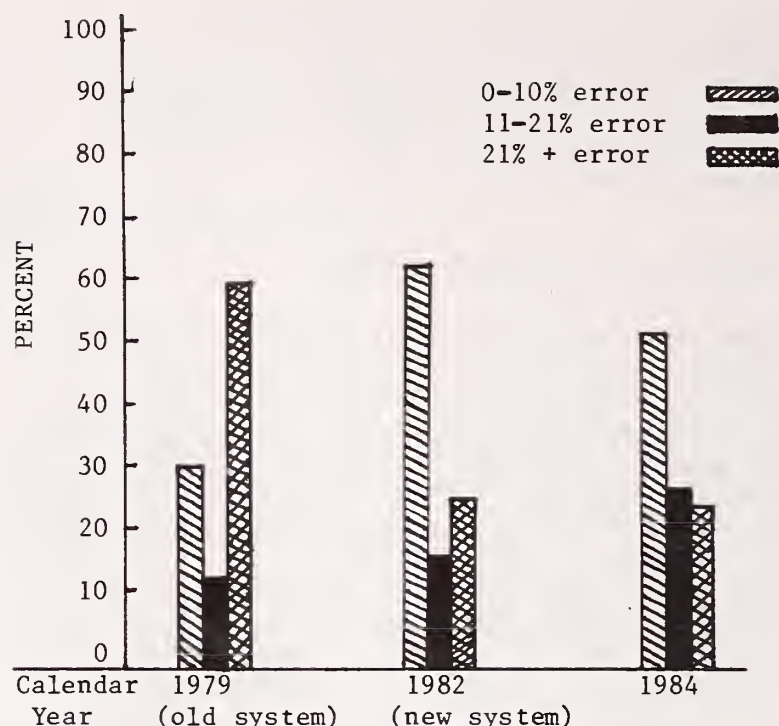


Figure 3.--Inventory error\* rates based on number of tree lots

\* The percentage of overrun or underrun that the inventory failed to predict based on the actual amount of trees packed.

### DISCUSSION

The reliability of a nursery inventory is ultimately gauged by its ability to consistently predict the actual amount of trees packed for shipment. This reliability can be significantly affected by factors not related to either the inventory design or process. These factors would be items not measured or that occurred after the inventory, such as:

1. Damage to trees from weather, animals, disease, or by mechanical means;
2. Changes in farming or cultural practices that alter typical growth patterns;
3. Short-notice changes in grading specifications.

As shown in the preceding bar graph, the new Bend Nursery inventory system has significantly reduced the frequency and magnitude of large errors but further improvement is needed. Ranger districts are reporting that inventory size class arrays are providing needed information about their Nursery stock. And, the Nursery is using the inventory statistics and size array to identify problem seed lots as well as to guide cultural operations and influence management decisions.

Since the original inventory design, the Bend Nursery system has been revised slightly to improve monitoring of data and improve convenience. The computer program now monitors the inventory number of plots taken and the bed footages measured and compares them to the prescribed inventory amounts. When the recorded inventory input data exceeds prescribed accuracy standards, the computer prints out a discrepancy message to alert the reviewer. Also, the accuracy standards have been tightened for the statistics to be run at 1 Standard Deviation. See the appendix computer printouts for details.

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#### APPENDIX

##### INSTRUCTIONS TO INVENTORY CREW-1984 TREE INVENTORY

Jim Schmahl will supervise all tree inventory operations this season. The prescribed procedures are described below.

1. Equipment Needed:  $\frac{1}{2}$ 'x4' and 1'x4' plot frame, 100 foot tape, tally sheets, caliper gauge.
2. Measure the specified distance between plots as listed in the heading. Avoid taking plots in both the first and last 5' of each bed. Next to the last plot in the bed, record the total bed length measured. Be sure to include the ends in your total figure.

3. On all 1-0, 2-0 tree lots, use  $\frac{1}{2}$ 'x4' plot. Count all live trees, unless the tree is obviously dying and is not expected to survive until winter. Record all count data without totaling. On 2-0 trees, do not count any 1-0 trees found. Take a minimum of 2 plots per lot and at least 1 plot for each seed bed.
4. On 2-0 and 1-1, 2-1 tree lots, measure-plot ratio is shown in the heading. On measure plots, measure the first and last tree in each of the seven rows in each plot to be measured. On each tree, measure the total height from the root collar to the tip of the bud and record to the nearest centimeter. Measure tree caliper near the root collar, preferably just above the collar swelling. Measure to the nearest half millimeter. Record as on the tally form in a dot format according to the tree size. Use additional tally sheets as needed to keep the dot tally legible.
5. The prescribed number of plots shown in the heading is the minimum needed. Should you be unable to get the minimum plots, advise Jim Schmahl. If you have taken all the required plots and have some remaining uninventoried ground, continue taking additional plots at the prescribed rate.

If for any reason it becomes apparent that there is a large error in the prescribed number of plots or the indicated total seed bed length, stop all work and bring the problem to Jim Schmahl's attention.

6. On 1-1 transplanted trees, use a 1' x 4' size plot! Measure and record as instructed for 2-0 age trees. There will only be 6 rows of trees per bed for measuring.
7. Turn in tally sheets daily once the seed lot is fully inventoried. If you observe unusual characteristics for a seed lot, such as high mortality, above average number of double tops, or spindly and stunted trees, please record your observations in narrative form on the bottom of the tally page.



7/25/84

## 2-0 AGE SEEDLING INVENTORY

Names L.H. & J.R.PTree Lot #14-8352, Lot BF 231, Sample 4 %, Size Plot 1/2'x4'Blk 15, No. Plots 18, Plot Spacing 23.5, M TreesSource Code 22-14-851-04000-55-81 SIARea(M) 18 Avail (M) 18

Bed Sub. Tot.	Plot No.	Sec	Bd	Live Tree Count	Bed Footage	Bed Sub. Tot.	Plot No.	Sec	Bd	Live Tree Count	Bed Footage
5	1	3	1	29 22			21				
	2			30 14			22				
	3			46 22			23				
	4			39 22			24				
	5			36 30			25				
	6			38 30			26				
	7			33 26			27				
	8			38 25			28				
	9			35 22			29				
	10			23 32			30				
	11			36 25			31				
	12			29 19			32				
	13			32 24			33				
	14			30 18			34				
	15			36 15			35				
	16			40 19			36				
	17			42 27			37				
	18			36 30	230		38				
	19						39				
	20						40				
Totals						Totals					

REMARKS:

Figure 4.--Field tally form #1

TREE MEASUREMENT DOT TALLY FORM

BLK #15 Sec. #3 Bd. #1

L.H. & J.R.P.

DATE 7/25/84

TREE LOT #14-8325

Ht in cm	Caliper Measurements								
	1-2mm	2½mm	3mm	3½mm	4mm	5mm	6mm	7mm	8+mm
1-6			•	•	∴				
7	•		••	•	∴				
8				•	∴	•			
9			•	•	∴	∴			
10			∴	∴	☐	••	•		
11			∴	•	∴	∴			
12			•	•	☒	∴			
13				•	☒	☒∴	∴		
14			∴		☐	☒☐	∴		
15					☐	☒☐	∴		
16					∴	☒∴	∴		
17					∴	☒•	☐		
18					∴	☒☐	∴	•	
19					∴	☒	∴	∴	
20					•	∴	∴	•	
21						☐	∴		
22						•	•		
23						•			
24						•	•		
25								•	

REMARKS
SOURCE CODE

Figure 5.--Field tally form #2



RJL		1-0 SEEDLING INVENTORY CALCULATIONS													
PLOT SIZE 1' x 4' = 1 1/2' x 4' = 2		TL# 14-8416	DATE 08/01/84												
		108-14-863-03000-55-77 SIA													
BLK:SEC:BED	TREES/PLOTS x SIZE =	LT/BF x BF	= GROSS VOL. )												
10: 10: 3	151/ 10	2	30.300 48.0 1.4												
10: 10: 4	534/ 46	2	23.217 219.0 5.1												
TOTAL	685/ 56 x 2 =	24.5 x 267	= 6.5												
Live Trees/Sq.Ft. 6															
DISCREPANCY-ACTUAL BF 267 VS. PROJECTED BF 277*															
DISCREPANCY-ACTUAL PLOTS TAKEN 56 VS. PROJECTED PLOTS OF 22*															
<table border="0"> <tr> <td colspan="2">INVENTORY DESIGN NEEDS</td> </tr> <tr> <td>DESIGNED ACCURACY STD.</td> <td>5 %</td> </tr> <tr> <td>COEFFICIENT OF VARIATION</td> <td>51.5%</td> </tr> <tr> <td>PERCENT SAMPLE NEEDED</td> <td>16.85</td> </tr> <tr> <td>NUMBER OF 1/2'x4' PLOTS NEEDED</td> <td>90</td> </tr> <tr> <td>PLOT SPACING</td> <td>3 ft.</td> </tr> </table>				INVENTORY DESIGN NEEDS		DESIGNED ACCURACY STD.	5 %	COEFFICIENT OF VARIATION	51.5%	PERCENT SAMPLE NEEDED	16.85	NUMBER OF 1/2'x4' PLOTS NEEDED	90	PLOT SPACING	3 ft.
INVENTORY DESIGN NEEDS															
DESIGNED ACCURACY STD.	5 %														
COEFFICIENT OF VARIATION	51.5%														
PERCENT SAMPLE NEEDED	16.85														
NUMBER OF 1/2'x4' PLOTS NEEDED	90														
PLOT SPACING	3 ft.														

TREELOT #14-8416

Figure 6. -- Computer printout for 1-0 seedling inventory calculations

RP

PLOT SIZE  
1' x 4' = 1  
1/2' x 4' = 2

2-0 SEEDLING INVENTORY CALCULATIONS

TL# 14-8352  
122-14-851-04000-55-81 SIA

DATE 07/31/84

TREE VOL. REQUESTED 18 (M)  
ADJUSTED REQUEST 18 (M)

BLK:SEC:BED	TREES/PLOTS	PLOT SIZE = LT/BF x BF	= GROSS VOL. (M) x	SHIPPING FACTOR = NET VOL. (M)	STATISTICS				
15: 3: 1	915/ 16	2	114.375	230.0	26.3	79%	20.8	MEAN	57.1875
								STANDARD DEVIATION	7.3
								COEFFICIENT OF VARIATION	12.8%
								ACTUAL % SAMPLE	3.48
								SUM OF X'S	915
								SUM OF X 2'S	53133
TOTAL	915/ 16	x 2	= 114.4	x 230.0	= 26.3	x	79%	=	20.8

Live Trees/Sq.Ft. 29

INVENTORY DESIGN NEEDS

DESIGNED ACCURACY STD. 7 %  
COEFFICIENT OF VARIATION 12.8%  
PERCENT SAMPLE NEEDED .65  
NUMBER OF 1/2'x4' PLOTS NEEDED 3  
PLOT SPACING 115 ft.

AVERAGE HEIGHT OF ALL TREES 14.7 cm  
AVERAGE HEIGHT OF SHIPPABLE TREES 15.2 cm

AVERAGE DIAMETER OF ALL TREES 4.9 mm  
AVERAGE DIAMETER OF SHIPPABLE TREES 5 mm

SHIPPING FACTOR  
[ 87.9 + 1/2 ( 10.44 ) ] x .85 = 79%

TREE LOT #14-8352

PERCENT OF GROSS TREES BY DIAMETER AND HEIGHT

```

*****
*
*ht. cm. ( in ) * 1.2 * 2 1/2 * 3 * 3 1/2 * 4-6 * 7+ *
*
*****
*
* 1-6 ( 2 1/2 ) * 0.0 * 0.0 * 0.0 * 0.4 * 0.8 * 0.0 *
*
*****
*
* 7-9 ( 3-4 ) * 0.4 * 0.0 * 1.2 * 1.2 * 5.2 * 0.0 *
*
*****
*
* 10-20 ( 4-8 ) * 0.0 * 9.9 * 2.8 * 2.9 * 78.3 * 1.6 *
*
*****
*
* 21+ ( 8+ ) * 0.0 * 0.0 * 0.0 * 0.0 * 5.6 * 0.4 *
*
*****
*

```

TREELOT # 14-8352

Figure 7.--Computer printout for 2-0 seedling inventory calculations



TREE SIZE STATISTICS  
TL # 14-8352

MEAN (GROSS) STD. ERROR OF ESTIMATE	4.9 mm 1.1%	MEAN (GROSS) STD. ERROR OF ESTIMATE	14.7 cm 1.7%
ACTUAL % SAMPLE TAKEN COEFFICIENT OF VARIATION	.95 17.6	ACTUAL % SAMPLE TAKEN COEFFICIENT OF VARIATION	.95% 26.4
NUMBER OF TREES SAMPLED	249	NUMBER OF TREES SAMPLED	249

DISCREPANCY - # OF TREES ENTERED IS 249\*  
SHOULD BE IN THIS RANGE: 184 - 225.6\*

\*key punching error detected by program)

Figure 8.--Computer printout for tree size calculations

245  
THE PLACERVILLE NURSERY SEEDLING LIFTING BAR

Alvin C. de Haas

**ABSTRACT:** Describes the attributes of an agitating lift bar that was developed at the Placerville Nursery, Camino, California.

#### INTRODUCTION

Historically, lifting of seedlings at the Placerville Nursery was done using a solid bar with non-movable fingers of staggered heights and lengths to break up the soil. The bar was pulled with a crawler tractor on a modified three-point hitch system to give power down to force it into the ground. This system worked relatively well but required constant monitoring and adjusting to do an adequate job of loosening the soil from the roots. Under some conditions it could not be adjusted to do an adequate job resulting in damaged roots during the manual lifting process.

Numerous times during the last 10 to 15 years different types of agitating or shaking lifters were tried with approximately the same unsuccessful results. The problems with the available machines were pulling the bulky drive apparatus through our heavy clay soil, and damaging seedling roots with the underground moving parts.

To solve the problem we decided to design and build a simple, streamlined lifting bar with agitating fingers. Thanks to valuable help from Engineer, Dan Tothoroh and Fabricator Earle Trimble, I think we have a mission accomplished.

#### ATTRIBUTES

1. Cutting bar designed light because it doesn't move independent of tractor and has less strain. The bar is made of 1-inch (2.5cm) by 5-inch (12.7cm) steel and the Shaker fingers are made of 1 1/2-inch (1.3cm) by 1 1/2-inch (3.8cm) steel mounted on a 3/4-inch (1.9cm) by 4-inch (10.2cm) plate.

2. Shaker fingers powered by a hydraulic motor.

3. The amount of movement and number of underground moving parts held to a minimum to reduce wear and maintenance cost.

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Paper presented at the combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Coeur d'Alene, Idaho, August 14-16, 1984.

Alvin de Haas is Production Assistant, Placerville Nursery, Forest Service-USDA, Camino, California.

4. Shaker fingers are divided in half and are 180° out of phase with each other to even the motor load and reduce the motor and component size. The hydraulic motor used was the smallest available.

5. The staggered finger lengths were based on the assumption that the narrow spacing was needed to provide adequate soil agitation and the wider spacing at the back end of the fingers would allow more of the loosened soil to fall through.

6. The parts underground were designed so as not to catch or damage seedling roots. There is a smooth flow from the leading edge of the cutting bar to the back of the agitating fingers with no acute angles or lips for seedlings to hang up on.

7. The power arm to shaker fingers follows directly behind the upright cutting arm keeping drag and wear to a minimum.

8. The angle of the shaker fingers to the cutting bar is adjustable.

9. The amplitude was made adjustable to experiment and find the optimum movement.

10. The frequency of movement has wide range of adjustability for fine tuning.

11. We found that the optimum movement was about 1 inch (2.5cm) and the frequency was six to eight movements per second.

For additional understanding refer to figure 1 and figure 2.

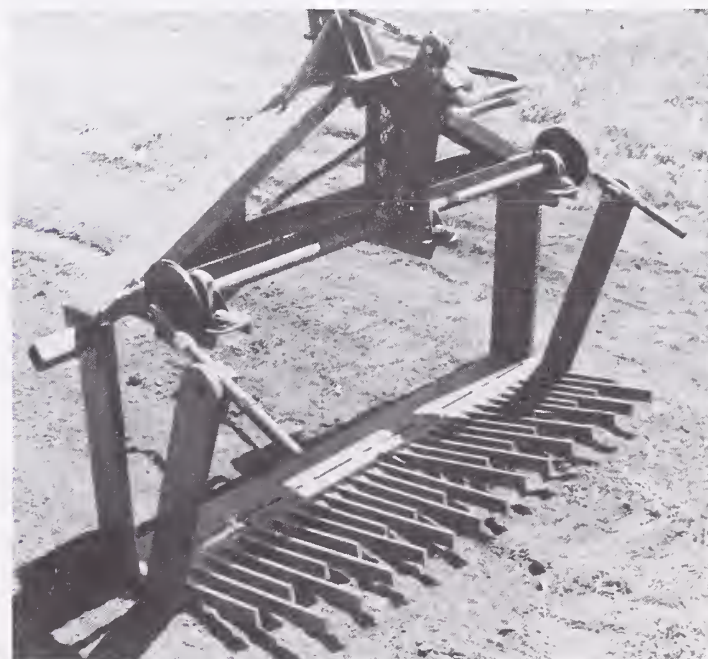


Figure 1.--Placerville Nursery seedling lifting bar.



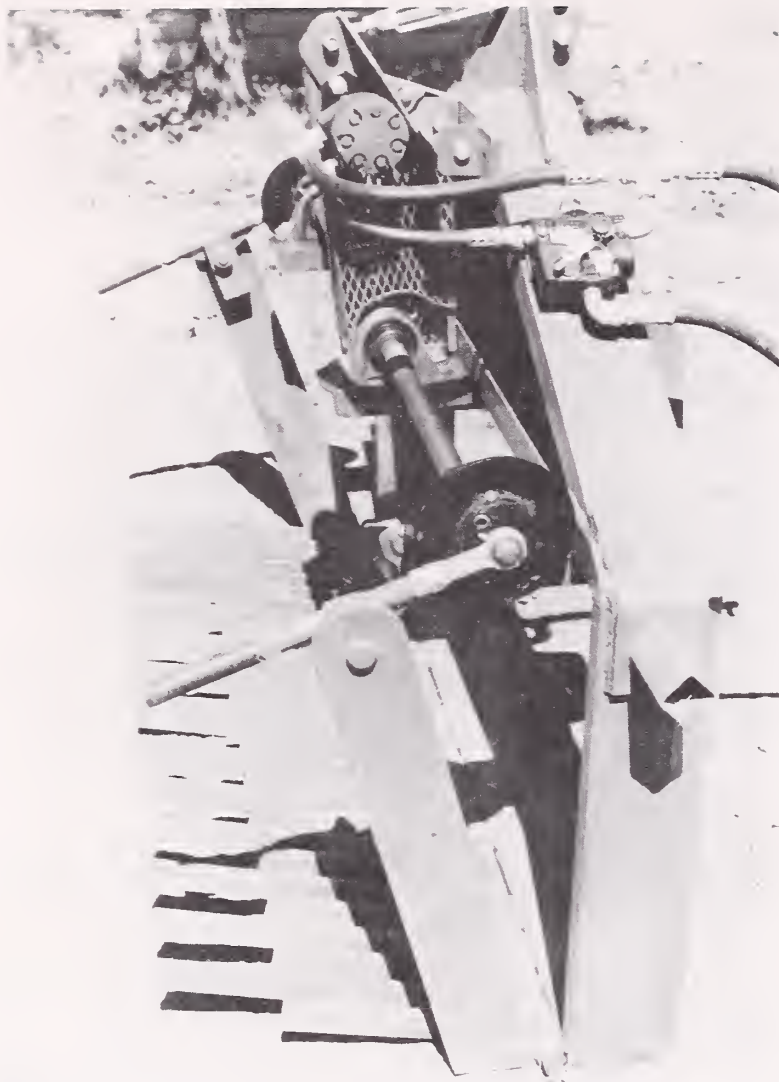


Figure 2.--Side view showing hydraulic motor, speed control, amplitude adjustment, piano type hinge for attaching agitating fingers, and the angle adjustment for agitating fingers.

## RESULTS

The lifter was not completed until after the season's production lifting was completed, but several rows of surplus seedlings were left to test it with. In one test the agitation was stopped on one side and not on the other. Then several people hand-lifted the seedlings to see if they could tell the difference. Without exception each person correctly identified which side had the agitation and which side did not.

Roots of seedlings from both sides were examined. Damaged roots, mainly stripped laterals, were easily found from the non-agitated side but were virtually nonexistent from the agitated side. Seedlings could be pulled from the ground singly from the agitated side in most cases and still not show signs of root stripping.

245  
SEEDLING NET-SPREADING AID

R. Don Langmo and James Washburn

**ABSTRACT:** Time studies of labor required to spread protective net over newly sown conifer seed beds led to construction of a cart to carry the roll of netting. Field tests showed that labor cost savings through use of the cart will pay for the equipment within one season.

## INTRODUCTION

During the 1983 planting season, work sampling time studies were made of the labor required at the Bend Pine Nursery to spread protective net over newly sown beds of pine seed. The net-spreading operation was selected for study because, though it is seasonal, it occurs every year and is relatively high in labor use and cost.

Management at the Bend nursery justifies use of the net because it prevents the destruction of seeds and sprouting seedlings by birds and rodents. There is special concern to avoid the substantial or complete destruction of a seed lot for which there is no replacement stock and, hence, the potential of complete disruption of a regeneration schedule.

Results of the 1983 net-spreading study were reported in a paper (Langmo 1983) presented at the Pacific Northwest Regional combined meeting of the American Society of Agricultural Engineers and the Canadian Society of Agricultural Engineers. That study showed a high proportion of delay time in the work of the net-spreading crew. The study also led to the objective of developing a cart to hold and carry the roll of net being spread in order to reduce nonproductive delays of labor. During the spring of 1984, the cart was built and comparative studies were made between manual and machine-assisted net laying.

The analysis of net-spreading and subsequent development of an alternative method was promoted through an Oregon State University Agricultural Experiment Station project administered by the Department of Agricultural and Resource Economics.

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Paper presented at the combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Coeur d'Alene, ID, August 14-16, 1984.

R. Don Langmo is Associate Professor and Industrial Engineer, Department of Agricultural and Resource Economics, Oregon State University, Corvallis, Oregon; James Washburn is Wage Leader, Bend Pine Nursery, USDA Forest Service, Bend, Oregon.

A working environment for the study was provided by the Forest Service Bend Pine Nursery. The nursery provided the necessary field facilities, the assistance of administrative staff and work crews, cost and production data, and ultimately the building of the prototype net carrier.

It should be kept in mind that the net-spreading methods and research results of this report are characteristic of the Bend Pine Nursery. Adaptation of the results to other nurseries must be evaluated in terms of the particular local conditions.

## PROCEDURE

### Bed Unit Characteristics

At the Bend Pine Nursery one complete net-covered bed unit consists of an area four bed-rows wide and is usually 400-feet (122-m) long. Wood stakes are driven into the ground at 15-foot (4.6-m) intervals along all the rows of the four bed-row unit. Nails are driven partially into the tops of all the stakes along the two outside edges and the longitudinal center of the four bed-row unit. The nails provide hooks for the net covering. Stake distribution for support of the net is shown in figures 1, 2 and 4. The width of



Figure 1.--Present method of spreading precut net. Three workers holding the net are near the end of the bed-row. Two workers following them stretch and hook the net to stakes.

the four beds and the walk lanes between them are covered by two strips of net each 12-feet (3.66-m) wide requiring a total net length per unit of



800 feet (244m). Where the center edges of the two lengths of net meet, they are slightly overlapped and hooked over the nails in the stakes in the center of the bed unit. Enough of the 24-foot (7.32-m) width of the net extends over the stakes on the outside rows to allow the net to drape to the ground. A short length of net resting on the ground is covered with soil, making a complete seal to prevent animal entry and restrain the net from lifting by wind. Rodents and birds capable of damaging the seeded beds are too large to get through the 5/8- by 3/4-inch (16-mm x 19-mm) mesh size of the net.

### Net-Spreading Techniques

Approximately two-thirds of the net installed each season has been used previously and cut to match the bed length. It is spread by a five-person team consisting of two crews. One crew of three workers holds the roll of net weighing about 17 pounds (7.7kg), with one person on each end and one person in the middle. The three workers slowly back down the lanes between the beds unrolling the net as they move. A second crew of two workers stretches the unrolled net flat across two bed-rows and hooks it to previously driven wood stakes that hold the net about one foot (0.3m) off the ground. The relative position of the three net unrollers and two spreaders is shown in figure 1.

The remaining one-third of the net installed is new material and comes on rolls of 4400 linear feet (1341m) that weigh about 187 pounds (85 kg) each. Spreading net from new rolls requires a team of 11 people. A pipe inserted through the center core of the net is set on rollers held by racks positioned at the end of the bed-rows. A worker with the end of the net in hand starts down the bed-row. At every interval of about 50 feet (15m) another worker steps in to help extend the net to the full length of the row. Two persons, starting at the far end of the row, stretch the net over two bed-rows simultaneously hooking it to the stakes along the rows. As the hooking progresses the workers that carry the net along the row length are released to return to the starting point to wait for completion of the hooking process. Workers are shown in figure 2 holding the net after the leading end



Figure 2.--An eleven-worker crew distributing new net along the length of a bed-row. After being stretched and hooked to stakes the net will be cut to fit the bed length.

has been carried the full length of a 400-foot (122-m) bed-row. After the net is spread and hooked on stakes over the length of the row, the net is cut. Then the roll and its supports are moved to the next two bed-rows to be covered.

When working with the prototype cart, the two-person crew that stretches and hooks the net to stakes follows the same operating practice used by the stretchers in the five-member team. The net unrolling crew, however, is reduced from three people to one person who guides the cart along the bed-rows. Details of the development and physical nature of the cart are described in the Results section.

### Time Study Method

In both the manual and cart assisted methods of net-spreading, only the time required by crews to spread net was measured. Material distribution, travel to and from the planting area, work interruptions, and rest breaks were not timed. Work sampling was used to determine the times for activities and delays required by the five-worker team to cover manually one unit of seed bed with precut net. Five observations per minute were made of each of the team members. The same work sampling frequency also was used to establish working and delay times for the three-person team distributing net with the aid of the prototype cart.

Only the total elapsed time was recorded during the few opportunities to observe the large team involved in manually spreading new net from uncut rolls. Though substantial delay time was not isolated, only the total worker time was needed for subsequent cost comparisons.

Comparative costs of the manual and machine-assisted methods of net application were based on the quantity of seed bed planting and the cost figures provided by the Bend Pine Nursery.

## RESULTS

### Manual Net-Spreading Time

Time studies revealed that a five-person team took 20 minutes to complete laying 800 feet (244m) of precut net over four bed-rows each being 400-feet (122-m) long. The two-person crew that stretched and hooked the net had work delays of about 13 percent. Their activity controlled the slow pace for the crew of three workers unrolling the net. In contrast, the unrollers accumulated delay time of 38 percent. Their work time consisted of holding and unrolling the net while slowly backing down the lane.

To spread new net from a roll located at the end of the bed-row, the eleven-worker team required a cycle of 21.4 minutes. Even while working during this cycle, nine members of the crew were simply holding the net (fig. 2). Though not isolated by measurement, much of each worker's time was spent



in an empty-handed return to the starting point of the row and waiting for the next turn to carry the net. Reflecting upon such unchallenging activity, (Barnes 1980) emphasizes that the activity "hold" is the least effective among the uses of human capability and it should be reduced or eliminated through work design or use of mechanical devices.

#### Mechanical Net-Spreading Aid

The need to reduce the ineffective delay and holding time identified with the manual work of unrolling net, suggested the potential use of a mechanical aid to hold the net. Initial sketches and ideas concerning design of a net-handling cart were expressed and adjusted at Oregon State University by building and modifying the three dimensional model shown in figure 3. Several features anticipated as desirable on a prototype

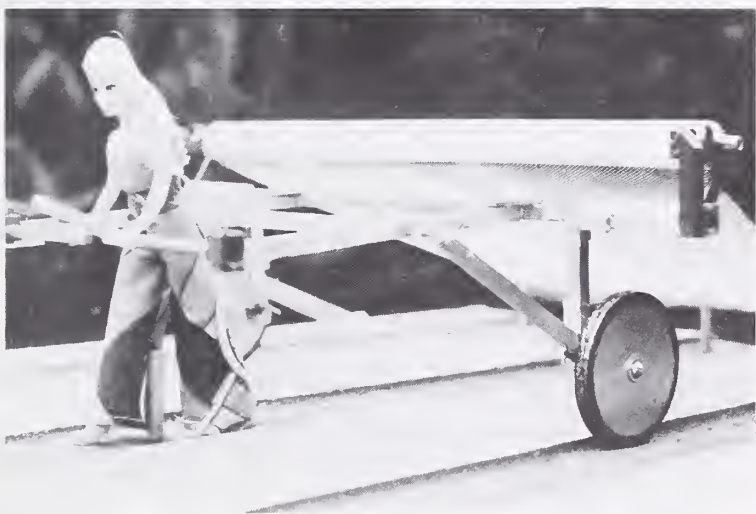


Figure 3.--An Oregon State University model was the pattern for building the labor saving cart to assist workers placing new or precut net over seeded bed-rows.

machine were developed on the model. These included:

1. Open bearing blocks to permit fast positioning and removal of the tubing on which the net was rolled.
2. Lateral adjustment of the bearing blocks to accommodate net widths from 12 to 14 feet (3.7 to 4.3m).
3. Wheel adjustment to allow for some variation in bed and lane widths.
4. Safety pads supported by brackets attached to the main frame and located behind the wheels. In case the machine tipped backwards the pads would stop the tilt before the net roll could drop on and disturb the seeded bed.
5. A front stabilizer bar shown near the right hand of the model operator in figure 3 that could be moved to the vertical position to give level support to the cart when it was unattended.

6. Adjustable components that locked and released through the use of screw clamps.

The complete cart, built at the Bend Pine Nursery, is illustrated in figure 4. It was pulled by one operator who moved along the bed 30 to 40 feet (9 to 12m) ahead of the two workers stretching and hooking net. Features developed on the model were utilized on the prototype. During construction of the cart specific dimensions were determined and design refinements for practicality were added. This included:

1. A 13-foot (4.0-m) frame width when the machine was adjusted to carry 12-foot (3.7-m) wide net.
2. Height from the ground to the center of the net roll was 4 feet (1.2m).
3. Unattended, the cart could rest in a horizontal position with the handle bar 3 feet (.9m) above the ground. A steel leg hinged to the center of the front reinforcement bar was held horizontally to the bar with a pin lock. By pulling the pin, the leg could be dropped to the vertical position to support the cart at rest.
4. The reinforcement bar located behind the handle (fig. 4) was 3 feet, 2 inches (1.0m) ahead of the main frame.
5. The distance between the main frame and handle bar was adjustable from 7 feet, 5 inches (2.3m) to 8 feet, 6 inches (2.6m). This allows some control by individual operators to balance the cart to fit their comfort preference.
6. The bicycle wheels were 26 inches x 1.75 inches (66.0 x 4.4cm).
7. The detail in figure 5 shows the sliding support that allows for minor changes in the distance between wheels. At the Bend Pine Nursery, the normal distance between wheels to straddle two bed-rows is about 10 feet (3m).



Figure 4.--During testing one worker guides the cart along the bed while two workers stretch and hook the net to stakes.





Figure 5.--There are several adjustable components on the machine. The one shown permits change in the distance between wheels to fit variations in bed width.

#### Cart Assisted Net-Spreading Time

The only change in the net-spreading activity was the substitution of the cart for two persons carrying net. If there were no change in the cycle time of 20 minutes to cover one seed-bed unit with precut net, then the reduction of the crew to three members would result in a 40 percent savings in labor time.

However, the average time for the studies of the three-worker team unfamiliar with the cart was 27.4 minutes per unit. Delay time for the worker pulling the cart was 37.4 percent in contrast to 2.6 percent delay for the two workers spreading and hooking the net. Once again, these two workers set the pace for the operation.

#### Comparative Costs

A change in the net-spreading method should provide a quality of performance equal to or better than a current system. Also, an operating cost advantage should develop that would pay for the cost of change to the new method in a reasonable time.

Production and cost data pertinent to a comparison of net-spreading alternatives for conditions experienced at the Bend Pine Nursery was provided as follows:

1. Bed-row length planted in 1984 = 86,320 feet (26,310m) or 108 units.
2. Used precut net to cover two-thirds of bed-rows = 57,550 feet (17 540m).
3. New net to cover one-third of bed-rows = 28,770 feet (8 770m).
4. Rolls of new 4,400-foot (1 341m) net used per season = 6.5 rolls.

The last 400 feet (122m) of each of the six new rolls of net used was spread by the five-operator team, the same as for precut net. This added 2,400 feet (731m) to the 57,550 feet (17 541m) of precut net totalling 59,950 feet (18 273m) of bed-row coverage by the five-operator team.

In turn, 2,400 feet (731m) of new net was not spread by the eleven-operator team, thus, reducing their production to 26,374 feet (8 039m).

In terms of time study units for cost purposes, the two teams spread the following amounts of net:

1. Precut net spread by five-operator team was 75 bed-row units of 800 feet.
2. New net spread by eleven-operator team was 33 bed-row units of 800 feet.

Labor costs for spreading net by the manual method included the cost of the five-operator team to cover 75 units plus the cost of the eleven-operator team covering 33 units. The cycle time in minutes per unit was converted to worker hours in each case. The stated labor rate per person at the Bend Pine Nursery was \$10 per hour including benefits.

Only one cost determination was needed for the cart assisted method since both precut and new rolls of net were handled by the machine and a three-operator team. This system, however, must account for the cost of the machine.

#### Manual net-spreading costs per season -

Five-worker team spreading net over 75 units:

$$\begin{aligned} &1.67 \text{ worker hours per unit} \times \\ &\$10 \text{ per hour} \times 75 \text{ units} &= \$1,253 \end{aligned}$$

Eleven-worker team spreading net over 33 units:

$$\begin{aligned} &3.94 \text{ worker hours per unit} \times \\ &\$10 \text{ per hour} \times 33 \text{ units} &= \$1,300 \end{aligned}$$

$$\text{Total cost per season for 108 units} = \$2,553.$$

#### Machine assisted net-spreading cost per season -

Three-worker team spreading net over 108 units:

$$\begin{aligned} &1.37 \text{ worker hours per unit} \times \\ &\$10 \text{ per hour} \times 108 \text{ units} &= \$1,480 \end{aligned}$$

#### Labor cost difference between manual and machine assisted methods -

$$\begin{aligned} \text{Manual method} &= \$2,553 \\ \text{Less machine assisted method} &= - \$1,480 \\ \text{Savings per season} &= \$1,073 \end{aligned}$$



#### Machine construction cost -

Materials	=	\$124
Fabrication labor	=	385
Overhead at 20% of material and labor	=	102
Interest on capital at 15%	=	92
Total machine cost		\$703

#### CONCLUSIONS AND DISCUSSION

The limits of the experience available indicate that the machine cost of \$703 will be paid by the \$1,073 savings projected for the cart assisted net-spreading system in .66 of a season. This estimate is conservative since it is based on the labor savings for three instead of five workers only during actual net-spreading time. It does not include other terminated and currently paid time for preparation, rest periods, and travel of the two released workers that would be charged normally to the net application.

A further safety margin in the cost analysis resulted from using the average performance time for the team unfamiliar with the mechanical net-spreading aid. Though the team of three with the cart did not match the 20 minute cycle time per bed-row unit of the five-worker team, analysis showed that the time per cycle for the cart team diminished with each sequential cycle. This is characteristic of performance as the learning process accommodates to a change in practice. Payment for the change of method would be accomplished in .57 of a season providing that the three-worker cart team with added experience could reduce its cycle time per bed-row unit to the 20.0 minutes cycle time of the present five-worker manual team.

Since the operating time to pay for the net-spreading aid is much less than one year, the 15 percent interest charge for capital for the machine likely would be necessary. This would reduce the payment period by an additional 14 percent.

In this study there was a cost advantage to the machine in that it was built by the user. Undoubtedly, its cost would have been considerably higher if the profit margin of a private fabricator was included.

More intensive use of the net spreading aid is needed to gain a more comprehensive understanding of its advantages and limitations. However, the brief experience this season has led to several suggestions concerning use of the cart and a few considerations for modifications in its design.

There was a high delay time, 37.4 percent, for the cart handler in contrast to the low delay, 2.6 percent, for the two stretchers. This extreme variance suggests that difficulties other than lack of training influenced the cycle time of the crew stretching the net. Two deterrents

to the stretchers following the machine were related to (1) the quality of the net, and (2) roll condition. The large roll of new net was delivered with an oblique mesh. This made it difficult and time consuming for the operators to stretch the net evenly across the supporting stakes. In addition, sometime during storage the net had been laid on an uneven surface which caused the fiberboard core to warp. As a result, the net would tend to flop off the roll causing surges in tension when it unrolled rather than flowing uniformly as the machine was moved along the bed-row.

Adjusting the design of the main frame of the cart to place the weight of the net roll closer to the top of the wheels would reduce forces at the handle bar when the wheels move over an uneven surface. Also, lowering the net roll would improve the visual contact and coordination between the cart handler and the net stretchers.

Use of wider tires would ease the work of moving the cart over soft or irregular soil. Tires with a 2.25-inch (57.15-mm) diameter cost about \$3 more than the 1.75-inch (44.45-mm) tires used.

It may be feasible to extend the usefulness and reduce the cost of a mechanical net-spreading aid by sharing it with other nurseries in the area that have different planting schedules.

Another means of increasing the function of the basic machine would result from modifying it to aid with the retrieval of net after the seedlings no longer need protection. A retrieval feature that could be installed and removed easily from the basic cart would have to serve the purposes of improving the efficiency of the retrieval operation and making the task easier for the workers involved.

Scheduling at the Bend Pine Nursery did not permit fabrication of the machine until the planting season was ended. The cart was tested on several units of one planting block. Since the opportunity for studies was limited, more extensive testing is recommended for next year.

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UPDATE ON NORTHEASTERN NURSERIES

John R. Scholtes

**ABSTRACT:** Nursery ownerships and production capacities are widely varied in the Northeastern Area of the USDA Forest Service. Nearly 100 nurseries are producing well over 200 million plants of up to 120 different species each year. Land ownership and landowner objectives are also very diverse. While several State-owned nurseries have closed recently, total nursery production and demand has remained steady.

#### DEFINITION OF AREA

I must first define the area of the United States that I will be discussing. For the purpose of this paper, the Northeastern Area encompasses 20 States. The northern perimeter begins with Minnesota and includes all States along the Canadian border east to Maine. The perimeter then extends south to Maryland, west to Missouri and north to Minnesota. This area is an administrative unit of the USDA Forest Service, State & Private Forestry, and is also congruous with the Eastern Region (Region 9) of the National Forest System (fig. 1).

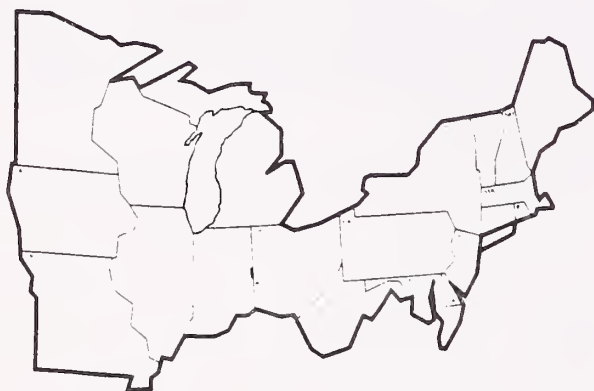


Figure 1.--Northeastern Area of the USDA Forest Service

Paper presented at combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Coeur d'Alene, ID, August 14-16, 1984.

John R. Scholtes is Nursery and Surface Mine Reclamation Specialist for the Northeastern Area, State & Private Forestry, USDA Forest Service.

#### NUMBER OF NURSERIES

Within this area there are close to 100 nurseries known to produce plant materials for forestry, reclamation, and conservation purposes. The actual count varies as existing nurseries close or new nurseries come on line. An approximate breakdown of ownership as of August 1984 is:

<u>Ownership</u>	<u>Approx. No. of Nurseries</u>
Private	52
State	27
Forest Industry	8
Federal	5
Soil and Water Conservation District	2

#### PRODUCTION

The last areawide survey of all nurseries producing stock for foresters, reclamation, and conservation purposes was completed in the spring of 1981. Nurseries contacted were asked for their 1980 production, type of production, and area available for production. The results of that survey are outlined in table 1.

More recent data are available for State-owned nurseries. At these nurseries, production varies from a few hundred thousand to over twenty million seedlings per year. Total production from State-owned nurseries averages around 100 million plants per year and seems to be relatively steady at this time. It is interesting to note that most northeastern State nurseries are operating at much lower production (many under half) than they were in the mid 1960's. This is because of the Federal Land Bank program operating at that time.

Presently, the increased interest in reforestation appears to be in the northern most States within our area and is supported primarily by forest industry. The largest advance in production facilities has been in new forest industry nurseries. We are currently aware of seven industry nurseries in the Lake States and Maine. State-owned nurseries have benefited little from this increased demand for seedlings. One reason is that there is currently little or no money available for production expansion.

Table 1.--Nurseries and production in the Northeast (as of 1980)

Ownership	Bareroot			Container		
	Number of Nurseries	Acres of Seedbed	1980 Production (Thousands)	Number of Nurseries	Square Ft. of Growing	1980 Production (Thousands)
Private	52	2,421	108,007	6	179,796	3,024
State	30	1,664	91,381	2	3,280	150
Forest Ind.	2	30	1,250	3	34,560	4,250
Federal	2	120	9,340	3	19,528	0
S&WCD*	2	41	6,750	0		0
Totals	88	4,276	216,728	14	237,164	7,424

\*S&WCD = Soil and Water Conservation Districts

Private nurseries are also gaining little from this increased production requirement. The reasons are varied and range all the way from some private growers having all the demand they are interested in filling through others not having funds to invest in expansion capital. On the industries' end, they may wish to keep the job in-house so they have more direct control of the product. Another reason for an industry to build its own nursery is to tie seedling production with tree improvement programs in which they are investing. Therefore, as in the southeastern States, forest industries are building and developing their own nurseries to meet most of their own seedling demands.

#### SPECIES

The list of species grown at State-owned nurseries in the Northeast is lengthy. It changes slightly from year to year but ranges between 110 and 120 species. This includes around 30 species of conifers and about 90 species of hardwoods, shrubs, vines and other species. (Copies of annual production from State-owned nurseries are available from this author. Listings include the species and quantities shipped by each State). Conifers make up over 80 percent of the total volume of seedlings shipped. It is interesting to note that eastern white pine is not the primary conifer produced. It comes in a poor second (16MM) to Norway (red) pine (28MM). White spruce (10MM) is the third most popular. It is also interesting to note that these are all Lake States and New England species. Of the hardwoods, black walnut (2.1MM) and black locust (1.9MM) are in highest demand. Autumn olive (1.7MM) is by far the most popular shrub.

#### LAND OWNERSHIP

Less than 10 percent of the commercial forest land in the Northeast is in Federal ownership, less than 9 percent is in State ownership, and just over 11 percent is owned by forest industry. Approximately 1.5 percent is owned by Indian nations, counties and municipalities. The remaining 69 percent of all commercial forest land in the Northeast is owned by private non-industrial forest land owners. This sector is made up of tree farmers, investors, farmers, and others who have varying degrees of experience and interest in managing forest land. There is a sizable portion of land owned by absentee landowners who spend little or no time managing the flora or fauna.

#### LANDOWNER OBJECTIVES

The objectives of landowners are even more variable than the types of landowners. These range from the tree farmer of the year for 1984 who manages a sugar bush and sells Christmas trees, logs, and other forest products from his 2,000-acre tree farm as his sole source of income to the individual who is holding his land to maintain the forest in its present condition. Woodlots are popular in farms and even small acreages since the energy crunch has raised the appeal of wood heat. Christmas tree plantations are also gaining in popularity as both primary and secondary sources of income.

The increased awareness gained from our environmental movement has popularized managing wooded acres for many values other than the production of wood. Owners often list objectives such as wildlife, general conservation, and esthetics, as the primary objectives for their forest land area. Thus, the reasons citizens



order seedlings also vary. The uses for seedlings recognized by various State nurseries and reported by buyers are listed below.

- Timber plantations
- Christmas trees
- Windbreaks and shelterbelts
- General conservation
- Rehabilitation of strip-mined land, old fields, and other disturbed sites
- Street trees for municipalities, DOT's, and other public lands
- Restoration of native vegetation, including production of species on endangered lists

#### RECENT DEVELOPMENT HIGHLIGHTS

- A. Several nurseries have closed in the past 3 years. These are listed below.
  - 1. Delaware - Two-year moratorium on sowing after nursery waterlines were stolen. Future uncertain.
  - 2. West Virginia - Clemons closed, Parsons remaining open.
  - 3. Ohio - Greensprings closed, Zanesville and Marietta remaining open.
  - 4. Pennsylvania - Mont Alto closed, Greenwood and Penn remaining open.
  - 5. Michigan - Howell (Southern Michigan Nursery) closed. Wyman remaining open.
- B. The State of Michigan has stopped production of seedlings for sale to private landowners. They have agreements with private growers to produce quality stock at reasonable prices. They plan to work out some system to distribute improved seed to private growers for the benefit of the private landowner.
- C. A large container nursery has opened which uses waste heat from a coal-fired generating plant. This facility is the Itasca Greenhouse at Cohasset, Minnesota. Ted Tower, formerly of the BIA, is the grower-manager.

#### CURRENT STATUS OF NORTHEASTERN NURSERIES

Overall nursery production has remained stable over the past several years. The closing of facilities mentioned above is really only a readjustment of State-owned nursery capacity after the high volume years of the Federal Landbank Program in the late 1960's. Production from State-owned nurseries is currently about half what it was during those years. The extra nursery capacity had been carried since that time. The recent economic climate made it necessary to shave off some of that capacity in order to economize. Otherwise, State production and sales have remained fairly even through these last few years and appear to remain strong. Private and industry nurseries are increasing in both numbers of facilities and production.

Container production is gaining very slowly and this is almost totally in industry-owned facilities. The few Federal, State, and privately-owned container facilities are remaining quite stable with no newly planned facilities known at this time.

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## PRE-EMERGENT HERBICIDE TRIAL IN WHITE SPRUCE

AT PINE RIDGE FOREST NURSERY //

Peter N. Au

ABSTRACT: Four pre-emergent herbicides, Pronamide, Chlorthal Dimethyl, Bifenox, and Napropamide were tested in the white spruce seedbed at Pine Ridge Forest Nursery, Alberta, Canada. Results showed that these herbicides, except Pronamide, could significantly reduce the amount of weeds and thus increase the plant growth of white spruce under local growing conditions.

## INTRODUCTION

Though weeds have been considered the major pest problem in forest nurseries, published information on the selection and use of effective herbicides is very limited. Perhaps this is due to the difference in local growing conditions and tree species, which causes individual tree nurseries to set up their own herbicide testing programs.

The objective of this herbicide trial was to investigate the effectiveness of certain pre-emergent herbicides applied after the spring seeding of white spruce at Pine Ridge Forest Nursery.

The management plan at Pine Ridge emphasizes tight control of chemicals used for crop maintenance. Therefore, the main purpose of these herbicide experiments was to gather information on how, when, and what herbicide can be effectively used when conventional methods such as mechanical and hand weeding would prove very costly.

## MATERIALS AND METHODS

The existing jack pine stand at Pine Ridge was cleared in 1977 to form the production fields. The soil consists of loamy sand to a depth of 180 feet (55 m). This sandy soil has very low organic matter which amounts to 0.5 to 1.0 percent.

Paper presented at combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Cour d'Alene, ID, August 14 - 16, 1984.

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The field that was assigned for this herbicide trial was sown with fall rye in 1977, oats and peas in 1979, and faba beans in 1980 to improve the organic content. In the spring of 1981 the seedbed was prepared for this test. On May 11, 1981, stratified seed of white spruce was sown at 500 seeds/yard<sup>2</sup> (400/m<sup>2</sup>) and the seedbed was hydromulched. On the same day (May 11, 1981), the testing herbicides were applied on top of the mulch according to the procedure of this experiment.

The treatments consisted of four pre-emergent herbicides plus control. The herbicides and their application rates were:

Treatment #1 : Pronamide (as KERB 50W, application rate : 0.2 g a.i./m<sup>2</sup>)

Treatment #2 : Chlorthal Dimethyl (as Dacthal 75W 0.6 g a.i./m<sup>2</sup>)

Treatment #3 : Bifenox (as Modown 4F, 0.24 g a.i./m<sup>2</sup>)

Treatment #4 : Napropamide (as Devrinol 50W, 0.5 g a.i./m<sup>2</sup>)

Treatment #5 : Control

Four replicates per treatment were used. Each plot size was 13.1 ft long by 4.1 ft wide (4 m by 1.25 m), or 6.25 yd<sup>2</sup> (5 m<sup>2</sup>) in area. Herbicides were mixed with 60 tsp (300 ml) of water and were applied by using a wagon-mounted CO<sub>2</sub> plot sprayer.

All treatments were located on one seedbed. The experimental design allowed four blocks of plots and each block contained one replicate of each treatment. Location of treatment (plot) within each block was chosen at random, including the control plots. A buffer zone 3.3 ft (1 m) long was allowed between plots (fig. 1).

The effect of respective herbicide treatment was assessed by the following methods:

- Weed count among treatments.
- Density count of spruce seedlings after complete germination and also after one winter.



- c. Visual assessment of spruce seedlings to check if physical damage occurred.
- d. Measurement of growth parameters such as stem height, root area index, and plant dry weight after one growing season.

Analyses of variance were performed on all data except visual assessment. Duncan's multiple range test was run to test the differences among treatments for significance.

## RESULTS AND DISCUSSION

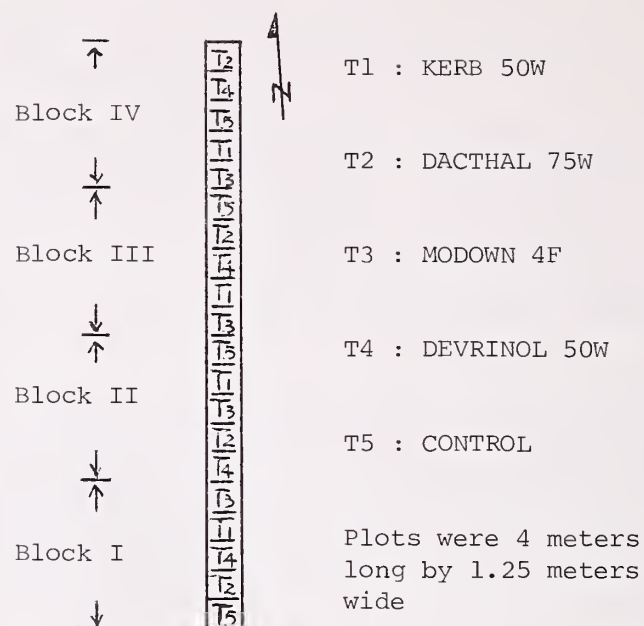
### Weed Counts

The weed assessment included all broadleaf species and grasses. Weeds were mainly hawksbeard, lambsquarter, buckwheat and grasses.

Test results in table 1 showed that all tested herbicides significantly reduced the amount of weeds in comparison to the control.

After the weed count on June 2, 1981, all plots were hand-weeded to check the residual effect of the herbicides. The weed count on June 25, 1981, showed similar results of reducing the amount of weeds in comparison to the control, except that the residual effect of KERB was significantly lower than the other three herbicides.

Figure 1.--Plot layout



### Seedling Density

Judging by the density count of spruce seedlings in table 1 after complete germination the herbicides did not reduce the germination of spruce seed, since there was no significant difference between respective treatments and the control.

Table 1.--Weed counts and density for white spruce seedbeds treated with four pre-emergent herbicides

Treatments	Weed counts (number per m <sup>2</sup> )				Seedling density (number per m <sup>2</sup> )	
	June 2/81		June 25/81		July/81	Sept./82
	Mean	Range	Mean	Range		
T1 - KERB 50W	<sup>1</sup> 49 b	29-62	35 b	25-49	326	258
T2 - DACTHAL 75W	52 b	19-111	20 a	15-29	325	286
T3 - MODOWN 4F	9 a	7-11	16 a	11-19	368	306
T4 - DEVRINOL 50W	39 b	16-88	14 a	7-22	340	291
T5 - CONTROL	80 c	43-114	57 c	43-76	350	236
					<sup>2</sup> N.S.	N.S.

<sup>1</sup>Numbers in vertical columns not followed by the same letters differ significantly at 5 percent level as judged by Duncan's multiple range test.

<sup>2</sup>N.S.: not significant.

Table 2.--Growth measurements of spruce seedlings in seedbeds treated with four pre-emergent herbicides

Treatment	Stem height (cm)	Root area index (cm <sup>2</sup> )	Plant Dry weight (mg)
T1 - KERB 50W	<sup>1</sup> 3.12 c	0.87 b	46.1 c
T2 - DACTHAL 75W	3.81 a	1.22 a	79.4 a
T3 - MODOWN 4F	3.76 a	1.20 a	79.0 a
T4 - DEVRINOL 50W	3.72 a	1.52 a	83.3 a
T5 - CONTROL	3.40 b	1.42 a	64.6 b

<sup>1</sup>Numbers in vertical columns not followed by the same letters differ significantly at 5 percent level as judged by Duncan's multiple range test.

The density count in September, 1982, showed that after one winter the survival of spruce seedlings from respective treatments was as good as those from the control. This result suggested that the health of spruce seedlings in treated plots was as good as the control before winter.

#### Seedling Growth

After one growing season, sample seedlings from each treatment and the control were dug out for growth measurements. Results from table 2 showed that seedlings from treatment plots of Devrinol, Modown, and Dacthal grew significantly taller and heavier. Perhaps this is due to the significant release from weed competition as shown in table 1.

Seedling samples from KERB-treated plots were significantly smaller than those of other treatments. Perhaps KERB did not maintain effectiveness as long as the other three herbicides as shown in the second weed count (table 1) and weeds came back faster to compete with the spruce seedlings.

#### CONCLUSION

The results of this experiment can only be applied to Pine Ridge due to its unique local growing conditions. Considering the scope of needs to collect practical information on weed control in the local area and to consider all possible environmental and physical conditions of the nursery site, this study was the tip of the iceberg for further studies.



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TOP MOWING AT VIEWCREST NURSERIES

John C. Doty

ABSTRACT: Top mowing Douglas-fir seedlings is a continuous cultural practice at Viewcrest Nurseries, Battle Ground, WA. A flail mower operated at 2,100 rpms and 5-7 mph covers 4-5 acres per hour. Cutting height, in 2-inch increments, is determined by height wanted at season's end.

Our top mowing has been limited to Douglas-fir as other species are not so much of a problem with excess top growth.

Four good reasons why we top mow:

1. For better root-shoot ratio, and thus better survival.
2. To reduce handling and container costs.
3. To balance out growth. In other words, to hold back the faster growing ones to allow the slower growing ones to catch up.
4. To shorten the overall height of all the seedlings, as in the case of 2-0's for transplanting.

When to top mow varies at different nurseries, and at different times of the season. About July 1 we start looking for indications. If and when 20-30 percent of the new tips are 2-3 inches (5-7.5 cm) beyond other tip growth, we make our move. It is important to work on succulent growth, and before tip buds start to form. Frequency of mowing varies from 2 to 3 weeks, depending on growth.

Cutting height is determined by the ultimate height wanted at season's end. We work in increments of 2 inches (5 cm) and allow 2-4 inches (5-10 cm) of final tip growth to achieve the height wanted.

On 2-0 seedlings, one or two cuttings will usually do the job--10 inches (25 cm) and 12 inches (30 cm), and a possible 14 inches (35 cm) works best. 2-0's for transplanting are kept at 9 inches (22.5 cm) if possible. Fall plug transplants are cut at 16 inches (40 cm) and 18 inches (45 cm), and final cut of 20 inches (50 cm) if needed to obtain uniform height of 22-24 inches (55-60 cm).

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Paper presented at combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Coeur d'Alene, ID, August 14-16, 1984.

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Sanitation is always a prime consideration. On top-mowed 2-0 stock, especially when doing a fairly heavy cut, we feel it necessary to spray with a good fungicide immediately after cutting. Fall-planted plugs and spring transplants haven't been sprayed so far. We may be changing our thinking on this, however.

Top mowing is done with rotary mowers, cycle mowers, and flail mowers. We settled on the latter. Its one big disadvantage is that the flails tend to knock some of the tips out of the way and not cut them. Speed seemed to be the answer here. We stumbled on a mower that could be reversed to give an upward slant cut on the tips, and as luck would have it, a "speed up" kit was available to increase the rpms. The mott mower filled the bill.

We crowded our pto speed to 2,100 rpms, 200 over the suggested pto rpm, and increased our ground speed to 5-7 mph (8-11 km/h), and covering 4-5 acres (1.6-2 ha) in an hour. We were now getting almost 100 percent of our tips cut, where at lower speeds we were losing about 30 percent, possibly due to bending action of the tractor, or other factors such as wind from the tractor fan.

One thing that is very important to keep in mind is safety, especially when working with these high rpms. As the flails are reversed, the driver will soon be aware of stings on the back of his neck. So we put a sheet metal guard ahead of the flails. Also it is important not to have anyone standing directly behind the flails, a guard would help here too.

Our try at changing the angle of the cut on the flails proved advantageous at the start, but the flails were soon back to a blunt stage, and we felt that speed was the best advantage we had. To remove and sharpen some 200 blades proved to be a monstrous task.

Earlier, we used a forward catcher to funnel the cut tips off in the paths, but our later cuttings were done with it off, the thoughts being that it tended to bend the tips over prior to cutting. We need to do some more testing here.

This season everything was about 2 weeks behind schedule, as well as having an unusually dry summer. So, our intentions for next year are to start our mowing 2-4 weeks earlier.

In our area, summers can be wet, and it is not always easy to control top growth with moisture and fertilizer retention. Thus, top mowing has become a continuous cultural practice in our nursery.

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NEW IDEAS IN FALL PLANTING //

Will B. Ellington

**ABSTRACT:** Tests of early fall planting of seedlings from Lava Nursery, Oregon, showed average survival rates better than those for spring planting. For successful early fall plantings, seedlings must not be lifted until soil moisture on the outplanting site is at acceptable risk levels. It is extremely important that seedlings be in perfect physiological synchronization with the planting site environment. A unified approach between the nursery and outplanting crews is necessary for successful early fall outplanting.

#### INTRODUCTION

Long-lasting snow packs in the high mountain forests of the western U.S. have caused great problems to the managers of those lands. Frequently, planting is delayed until June or July by snow on the units or in the roads leading to them. Seedlings for these units have generally been lifted in January or February, meaning long storage periods of 4 months or more. When these weakened seedlings are finally planted they are immediately exposed to severe heat and low humidity before they can initiate critical root growth necessary to survive. As a result severe outplanting losses have occurred.

These problems have become extremely important in recent years because of the greater dependence upon high-elevation forest lands in the evolution of managed forests in the West. Early efforts at fall planting were not successful because they were too late in the season. These failures came from a lack of knowledge about the growth dynamics of conifers native to these high lands where severe cold persisted for long winter periods alternating with severe heat and dryness in the summer periods. These trees are very different from the Douglas-fir and ponderosa pine grown for lower elevations.

Recent research by Dr. Edward Stone at the University of California, Berkeley, revealed that significant root growth potential in the early fall period was a feature of the true fir species native to the high mountains of California. This fact was confirmed by our observations at Lava Nursery, which is located in an identical climatic regime at 2,000-feet (600 m) elevation in the northern Oregon Cascades, an elevation equivalent

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Paper presented at the combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Coeur d'Alene, ID, August 14-16, 1984.

Will B. Ellington is President of the Lava Nursery, Inc., Parkdale, OR

to about 4,000 feet (1200 m) in northern California and 5,000 feet (1500 m) in the southern Sierra Nevada. At Lava, summer drought causes root and shoot growth to cease about the middle of July when buds are formed. As the environment modifies in September with shorter days and cooler nights, these high-elevation true firs initiate root activity with elongation appearing about mid October.

In other research, Dr. Steven Radosevich, then of the University of California and now at Oregon State University, found high levels of photosynthesis in these same species in the period from October to December. This fact triggered my curiosity in 1981 to try to plant some of these species on some test plots in areas of known past difficulty due to late snow packs. Could I successfully transplant trees in early October?

#### METHODS AND PROCEDURES

Discussions with other scientists and foresters in Oregon and California brought out additional information and I was encouraged to give the test a try. Three California companies with considerable high-elevation true fir forest land agreed to cooperate by furnishing areas of machine-cleared brush field conversion land for the plots. These companies were International Paper Company (now Fruit Growers Supply Company), Southern Pacific Land Company, and Beaty and Associates who administer the old Red River Company lands.

Plots were located in three separate areas ranging from north of Mt. Shasta between the Shasta and Butte Valleys, east of Mt. Shasta toward the Modoc lava country, and north of Chester California on Swain Mt. All of these locations were above 5,500-feet (1675 m) elevation in volcanic-origin soils. Annual precipitation averages between 40 and 60 inches (101.6 and 152.4 cm), most of which is snow that persists until July in many years.

The plots were planted during the fall of 1981 in 33.3-foot (9.14 m) squares with 100 trees on a 3.3-ft. (1 m) grid with corners and rows staked. Trees were planted as close to these grid points as possible so that they could be found again for survival inventories. Three plots were planted at each location to test exposure effects: open southern exposure, partially shaded southern exposure, and open northern exposure. Trees for the plots were lifted at the nursery in late September and transported on ice directly to the planting locations. Three trees were root pruned to 9 inches (22.9 cm) before being packed in the normal manner in three-layer bags. On the plots, the trees were planted with hoedad or shovel and



all planting was completed within 4 days after lifting. The plots were revisited several times later in the fall to check on root growth on extra seedlings that had been planted outside the plots for that purpose. Root growth was observed in about 3 weeks, which was late October, and continued until early December when snow covered the plots. These evaluations have been repeated each fall since then.

In order to compare the test technique with the normal spring planting, plots were established the following spring (1982) adjacent to the fall plantings whenever possible.

## RESULTS AND DISCUSSION

When checked in the late summer of 1983, the fall plantings had a mean survival of 86.1 percent compared to 81.7 percent for the spring-planted stock (Table 1).

Table 1.--Comparison of survival rates of fall vs spring-planted red fir seedlings.

Land Ownership	Fall Planting 1 (Pct. survival)	Spring Planting 2 (Pct. survival)	Aspect
Beaty & Assoc.	88	67	North
Beaty & Assoc.	92	72	South
Beaty & Assoc.	93	85	South w/shade
S.P.L. Co.	90	100	North
S.P.L. Co.	94	91	South
S.P.L. Co.	95	65	South w/shade
I.P.-F.G.S. Co.	84	78	North
I.P.-F.G.S. Co.	64	88	South
I.P.-F.G.S. Co.	75	89	South w/shade
Average	86.1	81.7	

<sup>1</sup>Fall plots were established in Oct. 1981 and evaluated 21 months later.

<sup>2</sup>Spring plots were established in May-June, 1982 and evaluated 15 months later.

Taken altogether, the fall planting is doing better than spring planting. Spring planting survival is much better than would normally be expected because the summers of 1982 and 1983 were exceptionally mild with periodic rains that reduced stress levels on the seedlings and allowed them to develop roots before temperatures and humidities became severe. More typical California summers would not have permitted these survival results. Fall-planted trees that have root development before winter emerge from the snow pack under far less stress than newly planted trees that have been exposed to the whole series of negative experiences from lifting through planting. The fall trees can initiate root growth in their normal sequence at the proper time in the spring. This activity can be observed as early as February under snow cover

at Lava Nursery. With far less stress and a functioning root system, early fall-planted seedlings can be expected to survive much better than those with inactive roots and suffering from handling and storage stresses incidental to spring planting activity.

The preliminary results of this test program have been discussed with many forest land managers in the West. The USDA Forest Service is beginning operational tests on the Shasta Trinity National Forest in California and on the Mt. Hood National Forest in Oregon. I expect that more interest in early fall planting will develop as a result of the current tests and as others become more well known. I am becoming more confident that this approach offers a dependable alternative for successful artificial regeneration of high-elevation forest lands, particularly with the true fir species.

## SOIL MOISTURE ON PLANTING SITE

Two very important factors must be considered in any application of this technique. I am sure that you have all thought about soil moisture while reading up to here.

You're right. Soil moisture on the outplanting site must be adequate to supply growing water for the seedlings for a sufficient period after planting so that root growth can actually occur. If there is inadequate moisture available, root growth will not initiate and the whole point of the fall planting concept is lost. Larry Ballew, forest consultant in Redding, California, has developed a system that very accurately defines soil moisture status and predicts the period of growing water availability. This allows the forester to time his fall planting precisely and minimize his risk. He can also determine whether the risk is too high and delay planting until spring and take his risks then. Since this early fall planting technique uses the "hot lifting" approach, the seedlings are not lifted until the soil moisture determination indicates acceptable risk levels. You also don't have to worry about seedling storage with this procedure.

## PHYSIOLOGICAL CONDITION OF SEEDLINGS

Another extremely important factor to consider is that seedlings used for early fall planting must be in perfect physiological synchronization with their intended environment. There is a very small "window" of opportunity to get the seedlings out of the nursery before they awaken fully from their summer drought-induced quiescence and into the plantation before root growth initiates. This means that early fall-plant seedlings must be grown in a cold climate nursery where the annual environmental cycle closely matches that of the plantations where they will be planted. If this sounds like a pitch for Lava Nursery---it is. Physiological preconditioning of seedlings to stressful environments is one reason why we established our nursery. Results from the last

7 years support this theory. Early fall planting success is one of those results.

Early fall planting should be an added benefit for tree planters. This puts more work into a generally low activity period of the tree planter's year. It allows him to plant in usually good weather in the beautiful high-elevation environment. At the nursery, fall is a very inactive time ordinarily. If we can lift a part of our crop in the fall it reduces the workload in the spring. This is particularly important in cold-climate nurseries where hussle, hassle, and chaos reign after long winters.

#### UNIFIED APPROACH

To be consistently successful I feel that this approach to planting must be done as a unified or full-service contract. This means that the nursery must coordinate directly with the planting contractor in order to properly time the critical activities. I don't think that the traditional, fractionated approach to planting where the land owner goes for lowest cost seedlings, low-bid planting, and low-bid everything will work. Last fall (1983) Lava Nursery sold 12,000 white and Shasta firs to the Shasta Trinity National Forest and contracted to plant them; payment was to be made upon final acceptance of the seedlings and the planting by the Forest Service. The project was located at 6,300-feet (1900 m) elevation on the southwest face of Mt. Sopris where snows often reach 20-foot (6 m) depths. Three previous unsuccessful efforts had been made to plant this brush field conversion.

Lava hired a highly regarded contractor, Mike Brash's Highland Timber Services of Mt. Shasta, California, to do the planting. Mike negotiated the price per acre after looking at the site and discussing it with the Forest Service silviculturist, Dave Trevisan. Mike was also given sample seedlings to provide him with an idea of what production problems he might have with them.

It is important to note here that we were specifying that these seedlings were to be planted with unpruned roots, some of which were laterals of 20 inches (50.8 cm). This specification was recommended by Lava on the basis that root elongation had begun in mid September so we did not want to destroy the delicate physiological balance of the seedlings by cutting off all of the root system "goodies". The Forest Service agreed and we mutually worded the spec's to allow some distortion of lateral roots in planting. "L" laterals were acceptable but not "J's". I might also note that Lava undercuts its seedlings in the beds at about 9 inches (22.9 cm). This reduced tap root length and that is the root element that must be prevented from being distorted in planting. Distorted lateral roots are not nearly as serious as "L" or "J" tap roots.

The Highland crew used 16-inch (40.6 cm) planting shovels, planted 700 trees per man per day in 7 hours working time, and made a 98 percent performance rating in the rigorous Forest Service

inspection. Lava Nursery and the Forest Service closely monitored the seedlings during lifting and planting with a PMS moisture stress "bomb" to determine stress levels. Readings were continued after planting for several weeks. The net observation was that the trees apparently became adapted to the plantation environment 4 days after planting. Moisture stress readings after that showed little difference from natural seedlings in adjacent forest stands. By early December, when snow finally covered the site, no stressed seedlings were observed.

What this shows is that coordinated, careful control of planting with all parties committed and paid to do the best job possible will yield top-quality results. We must wait until next September to see for certain what the survival results will be, but one thing certain is that another spring plant would have been doomed. There was still 4 feet of snow on the location in early May, 1984.

Lava Nursery is trying to obtain more fall planting projects and will continue its tests if research funds can be obtained through the Small Business Innovative Research Program. We hope to be working with some of you folks in the future. If you have questions, comments, or help to offer, we would be pleased to hear from you at the following address:

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P. O. Box 370  
Parkdale, OR 97041

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Jay R. Faulconer and Barbara E. Thompson

**ABSTRACT:** Standards for assessing forest seedling quality are shifting from traditional morphological characteristics to internal, physiological condition. Several tests for evaluating seedling physiological condition are described, and potential applications are suggested. Example test results from 1982 through 1984 are presented for coastal Douglas-fir seedlings; their implications for the nursery manager are discussed.

## INTRODUCTION

Standards of nursery seedling quality have long been an important issue among nursery managers and regeneration foresters. Traditionally, quality standards have been based on external morphological characteristics such as height, diameter, and root mass. More recently, attention has shifted to aspects of internal physiological vigor as a basis for rating seedlings. Tests for evaluating several attributes of seedling vigor have been developed which can provide valuable information regarding the physiological status of nursery stock. Although these tests are well documented in the literature, they have yet to become standard practice for most of the industry. This is probably due to the fact that most nursery managers and foresters have neither the time nor the facilities required for conducting them in a reliable manner. Recently, however, laboratories have been established in the Northwest that will perform seedling quality testing for interested parties. Because of the increasing availability of such services, now is a good time to evaluate some of the practical benefits of the various tests.

There are many good reasons to have reliable physiological information on nursery seedlings at every stage of the production cycle. This paper will be restricted to a brief discussion of the tests currently utilized by International Paper Company and a few of the more critical applications where they can be of particular value. To illustrate these applications, some example results from our testing service will be presented. It should be understood that the data were not collected as part of a formally designed research study, but are instead a summary of many tests performed for ourselves and other companies and

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agencies during the 1982-83 and 1983-84 lifting/planting seasons. Results will be restricted to those from Douglas-fir seedlings from seed zones west of the Cascades and grown at west-side nurseries in Oregon and Washington. The general principles, however, are applicable to nursery production in any region.

## THE TESTS

There are five components to International Paper's testing program. They include an assessment of 1) root-growth potential (RGP), 2) frost-hardiness, 3) dormancy release, 4) greenhouse survival, and 5) standard morphological measurements. Briefly, they are conducted as follows:

### Root Growth Potential:

Sample seedlings are potted in a rooting medium and placed in a greenhouse where optimum growing conditions (warm temperatures, long photoperiod, frequent irrigation) are maintained. This is similar to the original method developed by Stone (1955). After a specified period (usually 28 days), the seedlings are carefully unpotted and new root growth is evaluated using a quantitative index similar to that suggested by Burdett (1979).

RGP is affected by both the overall vigor of the seedlings and recent handling practices, such as duration of cold-storage. The seasonal development of RGP has been linked to the dormancy cycle so that, in general, it increases with the number of chilling hours received. However, because chilling requirement varies with seed origin, and since accumulated chilling hours can be nullified by unseasonably warm temperatures (Nienstadt 1967, Krugman and Stone 1966), RGP is difficult to predict during the lifting season. Because of this, testing RGP is most useful at the time of lifting and at planting time. With this information, one may assess the appropriateness of the lifting date and the effects of cold storage on the RGP of seedlings lifted on that particular date. The value of determining this aspect of seedling quality is underscored by the fact that several investigators have established a positive correlation between laboratory RGP and subsequent field performance for several coniferous species (Stone 1955, Stone and others 1961, Jenkinson 1976-77, Burdett 1979).

### Frost-Hardiness:

Sample seedlings are frozen to three or four temperatures in a programmable freezing chamber, after which they are placed in the greenhouse. After five days, injury is assessed visually using a method in which



damage to the stem (cambium), buds, and needles is rated separately in order to arrive at an overall rating for each seedling. This whole-seedling method is superior to evaluation methods which consider only a portion of seedling tissues. It also makes it possible to assess the differential development of frost-hardiness within the various seedling tissues during the hardening and dehardening processes. After injury is assessed, a curve is constructed which reflects the amount of mortality at each temperature; the  $LT_{50}$  (temperature resulting in 50% mortality) is then determined from this curve.

#### Dormancy Release; Greenhouse Survival:

Sample seedlings are potted and placed in a greenhouse under optimum growing conditions. After 28 days, percent bud-break and survival are determined. Dormancy release is a function of chilling hours received and is thus linked to RGP. A high percentage of burst buds indicates that the chilling requirement has been fulfilled and the seedlings are at or past the optimum lifting window. Poor greenhouse survival is typical of a seedling lot of seriously sub-standard vigor. In such cases, this test may be the most conclusive indicator of seedling quality.

#### Morphological Evaluation:

Although physiological vigor is the major focus of the testing program, size and balance are still important descriptive attributes of seedling quality. Measurements are made of height, diameter, terminal bud height, and shoot/root dry weight ratio. Most of these measurements will be familiar to nursery managers and need no further explanation. For coastal Douglas-fir, mid-winter terminal bud height has been positively correlated with primordia (needle) number on the following spring's terminal flush (Thompson, unpublished report 1984). Presumably, then, given the same physiological status, balanced seedlings with larger buds will have a greater growth potential during the first year on the plantation.

#### CULTURAL PRACTICES AND SEEDLING QUALITY

For the nursery manager, one of the most valuable applications of seedling testing is to assess the effects of nursery cultural regimes on seedling physiology. Nursery practices can have profound impacts on both overall seedling vigor as expressed by frost-hardiness and RGP and on the rate and degree of dormancy development. For lots tested at International Paper's lab, nursery of origin had greater influence on test results than did seed source. The variation between nurseries did not follow any consistent latitudinal or elevational gradient based on nursery location. Evidently, nursery practices are able to mask any variation due to seed source or nursery location. This is illustrated by the frost-hardiness development curves for

seedlings of two Douglas-fir seed zones, each of which were grown at two separate west-side nurseries (fig. 1). In general, seedlings from Nursery B hardened four weeks earlier than those at Nursery A. Besides suggesting that the potential for frost damage was greater at Nursery A, this delay in hardening raises the concern about proper development of dormancy, as we shall see in the next section.

Most nursery practices have been developed to tailor the morphological characteristics of conifer seedlings. These include sowing density, fertilizer schedules, root pruning, and top mowing, to mention a few. Nursery managers vary these practices in order to attain certain morphological targets. Other practices, such as late-summer water stressing and wrenching, are meant to trigger the dormancy induction process. The effect of most of these practices on physiological quality at lifting remains largely uninvestigated. Frost-hardiness, RGP, and dormancy development are all subject to cultural influence, particularly by such practices as top mowing and root pruning. These activities may significantly alter the hormonal balance within seedlings (Lavender and Hermann 1970).

International Paper has utilized seedling testing as a basic component of nursery research for several years. It has proven to be a very valuable tool for gauging the effect of several nursery practices on seedling quality. A thorough understanding of the physiological implications of any cultural

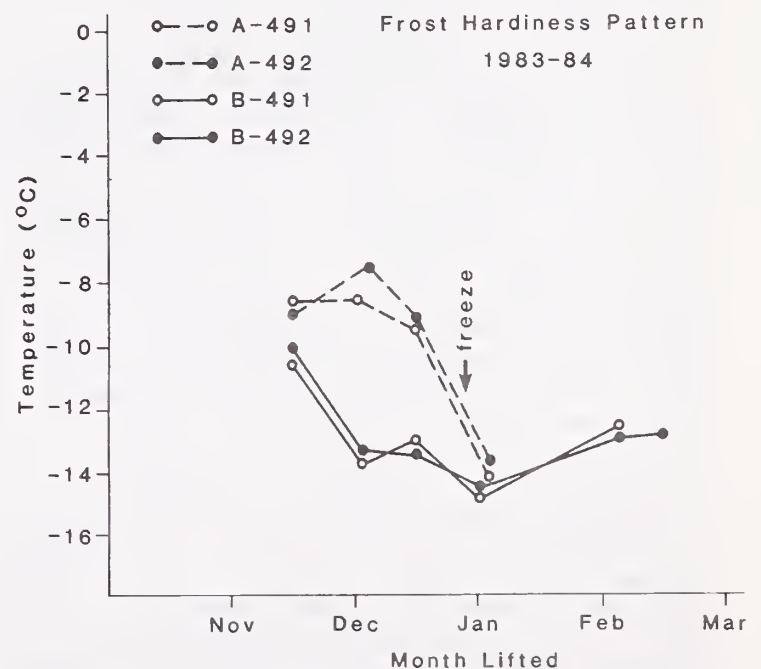


Figure 1.--Frost-hardiness pattern of two Douglas-fir seed zones (491, 492) each grown at two separate west-side nurseries (A, B). Arrow indicates approximate timing of a severe freeze in late December 1983. Data points are  $LT_{50}$ 's, or the temperature at which 50% of the seedlings in the lot did not survive the test.



technique is vital to the consistent production of quality stock.

#### COLD-HARDENING, DORMANCY, AND LIFTING

In addition to evaluation of cultural practices, seedling testing, especially for frost-hardiness, can be very useful as a guide for nursery managers during the fall hardening period and lifting season. Because the frost-hardiness test is one of the quickest to perform, it can be used to track the physiological changes occurring in seedlings during the hardening period. One direct application of the results is to determine the need for frost protection.

The potential for damage to seedlings by early fall frosts prior to adequate hardening is well recognized. Several methods for preventing or minimizing such damage have been devised, the most common being overhead sprinkling. However, there often is uncertainty as to the extent to which seedlings have hardened at any point in time, making it difficult to know when frost protection is truly warranted. Tracking the development of frost-hardiness during the fall helps to eliminate the guesswork. As the seedlings harden, appropriate adjustments may be made to temperature alarms and automatic sprinkler systems, and thus avoid unnecessary frost protection (and the risk of mechanical ice damage).

Another valuable application of frost-hardiness testing is to assess the general vigor and liftability of seedlings as the lifting season approaches. In addition to a direct measurement of a seedling's ability to withstand cold temperatures, frost-hardiness can provide an index of overall physiological status. Although frost-hardiness and dormancy are not technically synonymous, it is generally accepted that both develop in response to the same set of changing environmental conditions (decreasing photoperiod, cool temperatures) (Alden and Hermann 1971). Thus, the same physiological changes that enhance a seedling's ability to withstand frost also improve its ability to withstand lifting and transplant shock. The degree of hardiness and rate of attainment are an integration of the environmental influences that have been experienced by the seedlings (Thompson, unpublished report 1983). By following the development of frost-hardiness, it is possible to assess the ability of seedlings to properly respond to the environmental cues responsible for the physiological changes resulting in general stress resistance. This ability is an indication of the overall vigor or health of the seedlings.

We have already seen that nursery cultural practices can alter or interfere with the ability of seedlings to properly respond to environmental cues. Data from the two previous testing seasons indicate that seedlings may

also exhibit annual variation in the rate and degree of frost-hardening.

During the fall and winter of 1982-83 coastal Douglas-fir seedlings displayed the typical pattern of gradually increasing hardiness in November and December, reaching maximum hardiness in January, followed by a rather rapid de-hardening during late February and March. When this trend is compared to the same type of test-generated curve for the following year (1983-84) it is apparent that, although the overall pattern is very similar, seedlings from the second year averaged 3-5° C less hardy at any given point between November and March (fig. 2). Another way to look at this is to say seedlings from 1983-84 were two to three weeks behind those of the previous year.

Because this variation was observed at all west-side nurseries tested, it seems likely that some environmental factor in effect across the entire region was responsible. The probable cause is annual variation in temperature patterns and the amount of chilling hours experienced by the seedlings during the early stages of cold-hardening and dormancy induction. In any case, the implications of decreased or delayed cold-hardening with respect to lifting date should be examined. In general, seedlings lifted during the early part of the 1983-84 lifting season were more likely to suffer handling damage and transplant shock than those lifted at the same time the previous year. Because frost-hardiness testing can identify such annual variation in hardening trends by November, the information can be used when scheduling lifting operations. During a year such as 1983-84, early lifting should be delayed if possible, or prioritized so that the hardiest lots are lifted first.

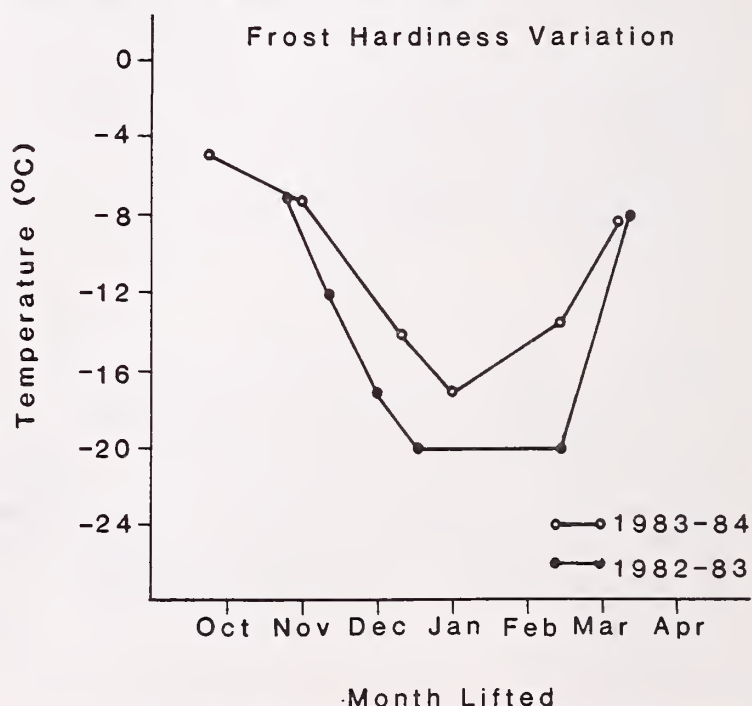


Figure 2.--Average frost-hardiness variation of coastal Douglas-fir seedlings grown in west-side nurseries in two successive years. Data points are LT<sub>50</sub>'s, or the temperature at which 50% of the seedlings did not survive the test.

## CONCLUSION

Seedling quality testing has many valuable applications for the nursery manager. It can assist in the production of quality stock and help to ensure that quality is not compromised during lifting operations. Eventually, standard curves illustrating the seasonal development of root-growth potential and frost-hardiness can be developed for the many provenances of the species utilized in regeneration programs. Such curves can be used as guides for nursery managers and foresters, enabling them to fine-tune lifting and planting schedules to most suitably match the condition of the seedlings.

Of course, the ultimate test of seedling quality is field performance. Many factors influence the performance of seedlings after they leave the nursery. These include post-lifting storage conditions, handling and planting techniques, planting site conditions, and post-planting environmental factors such as weather, vegetative competition, and animal damage. Some or all of these influences combine to make predictions of field performance based on seedling test results difficult. This difficulty does not detract from the value of such tests. On the contrary, the potential adversity confronting seedlings during and after planting make it more critical for both nursery managers and foresters to be confident in the quality of planting stock as it leaves the nursery. With this baseline information, the forester may then wish to conduct tests to evaluate the effects of post-lifting storage and handling on seedling quality. By ensuring that seedling quality is enhanced, or at least maintained, through all phases of reforestation programs, the success of such programs will be improved.

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THE EFFECT OF SOWING DEPTH AND MULCH ON GERMINATION

AND 1+0 GROWTH OF DOUGLAS-FIR SEEDLINGS //

R. D. [Guariglia and B. E.] Thompson

**ABSTRACT:** The effect of three sowing depths (surface, 1/4 inch, and 1/2 inch) and four mulches (sand, hydromulch, fresh alder sawdust, composted alder sawdust) on germination and 1+0 growth of Douglas-fir 252-1.0 seedlings was evaluated at International Paper Company's Western Forest Research Center near Lebanon, Oregon. Germination percent, 1+0 seedling bed density, and 1+0 diameter were best for seed sown at 1/4 inch soil depth. 1+0 seedling shoot height and oven-dry shoot weight were best for seed sown on the surface or at 1/4 inch depth. The poorest performance resulted from seed sown at 1/2 inch soil depth. Germination rate was not affected by sowing depth. Mulching with alder sawdust modified soil temperatures in the seed zone which significantly increased seed germination and 1+0 shoot development relative to other mulches tested. Seed covered with hydromulch experienced colder soil temperatures producing the poorest germination rate and percent.

#### INTRODUCTION

Sowing depth and mulch treatments have been shown to affect germination of slash pine seed under southern nursery conditions (Rowan 1980). Rowan (1982) also demonstrated that emergence of loblolly and slash pine seed varied according to mulch type and nursery climatic conditions immediately following sowing.

Very little information, however, has been reported regarding the effect of sowing depth and mulch on germination of Douglas-fir seed. Most northwest nurseries do not mulch Douglas-fir seedbeds and sow between 1/8 and 1/4 inch soil depth (Duryea 1984; Thompson 1984).

Sorenson (1978) found 1+0 Douglas-fir shoot height could be increased 0.5 mm per day of earlier sowing between April 23 and May 12.

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Several northwest nurseries begin sowing in March and continue through June (Duryea 1984; Thompson 1984). Early spring soil conditions are often cold and wet, creating an unfavorable environment for seed germination (Sutherland and Anderson 1980). Mulching has been shown to modify soil thermal and moisture properties (Cochran 1969; McDonald 1984). Mulches that produce warmer seedbed temperatures could improve germination of Douglas-fir seed and allow sowing to begin earlier in the spring.

High seedbed temperatures that occur later during the summer can retard growth by adversely affecting seedling physiological processes such as respiration and photosynthesis (Kramer and Kozlowski 1979). Again, mulching could be used to cool high seedbed temperatures and encourage growth of Douglas-fir seedlings.

The purpose of this study was to examine the effect of four mulch materials and three sowing depths on rate and amount of Douglas-fir seed germination, 1+0 seedling bed densities, and 1+0 seedling size at International Paper Company's Western Forest Research Center near Lebanon, Oregon.

#### METHODS AND DESIGN

After 10 weeks of cold stratification at 2°C, Douglas-fir seed from zone 252-1.0 were sown on May 21, 1983 at three depths (surface, 1/4 inch, 1/2 inch) and at a density of 188 pure live seed per bedfoot. Sowing was done with an eight-drill Oyjord seeder. The six center drills were grouped into three paired rows representing the three sowing depths. After sowing, 20-foot sections were mulched with 1/4 inch of either sand, hydromulch, <sup>1/</sup><sub>2</sub> fresh alder sawdust, or composted alder sawdust. Study plots received normal irrigation and cultural practices throughout the growing season. The study was arranged in a split-plot design with four replicates (nursery beds). Main plots were the mulch treatments assigned in a consistent pattern, and sowing depths were the subplots.

<sup>1/</sup> Turfiber, R. Superior Fiber Products.

<sup>2/</sup> Mention of trade name is solely to identify material used and does not constitute an endorsement by International Paper Company.

Germination was recorded weekly for 9 weeks from two measurement plots established in each treatment combination. The number of days between sowing and 50 percent germination was used to indicate rate of seed germination. Germination percent was calculated as the total number of germinants divided by the number of pure live seed sown. Seedling bed densities and morphological measurements were recorded in October.

Soil temperatures (1/4 inch soil depth) were recorded twice a week in the afternoons from June through September. Data were evaluated using standard analysis of variance procedures (SIPS 1981).

## RESULTS

### Sowing Depth X Mulch:

Total germination of Douglas-fir seed, expressed as germination percent, was significantly affected by sowing depth (table 1). Germination percent was best for the 1/4 inch depth followed by surface and 1/2 inch depths, respectively. The same pattern existed for the 1+0 bed density. Mulched surface-sown seed had better germination percent than when unmulched. Germination rate (day of 50 percent germination) was not affected by sowing depth.

Sowing depth significantly influenced 1+0 seedling size (table 1). Surface and 1/4 inch depths produced seedlings with similar height, caliper, and oven-dry shoot weight. These were consistently larger than seedlings grown from seed sown at the 1/2 inch depth.

### Mulch:

Mulch treatments significantly affected germination percent, rate, 1+0 seedling density, and June soil temperatures (fig. 1 and 2). In general, the warmest soil temperatures were associated with the sawdust mulches which had the best germination percent, rate, and 1+0 seedling density. Hydromulch, however, had the lowest June soil temperatures and overall the poorest germination and 1+0 seedling density.

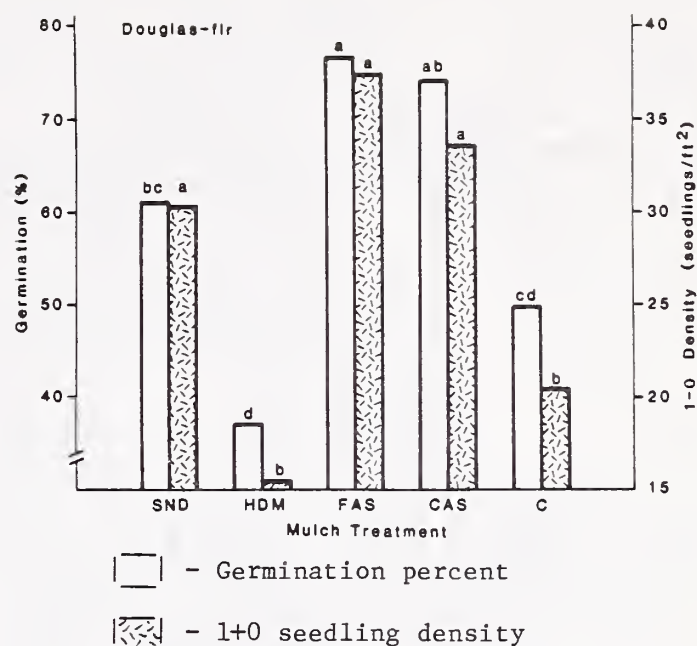


Figure 1.--Total germination percent and 1+0 seedling density for five mulch treatments; SND-Sand, HDM-Hydromulch, FAS-Fresh alder sawdust, CAS-Composted alder sawdust and C-Control (no mulch). Values with the same letter within each variable are not significantly different at  $p=0.05$ .

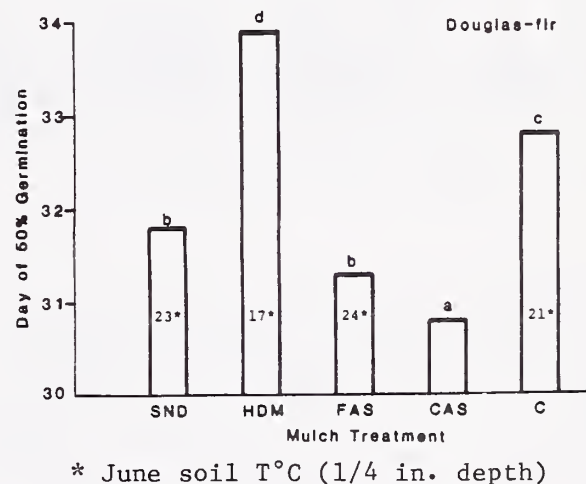


Figure 2.--Germination rate (day of 50 percent germination) for five mulch treatments; SND-Sand, HDM-Hydromulch, FAS-Fresh alder sawdust, CAS-Composted alder sawdust and C-Control (no mulch). Values with the same letter are not significantly different at  $p=0.05$ .

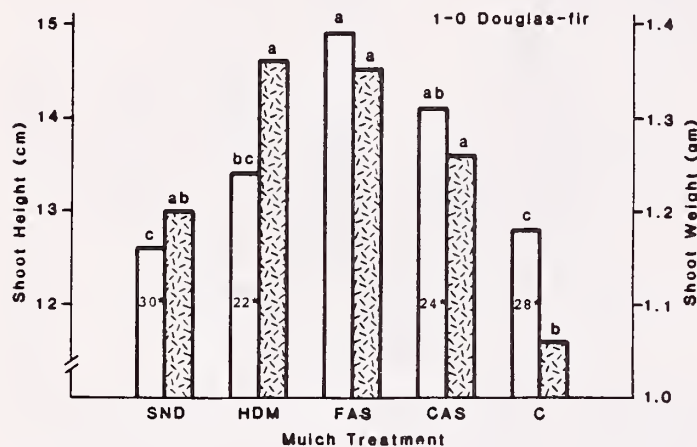
Table 1.--Germination percent and rate, seedling bed density, height, diameter, and oven-dry shoot weight

DEPTH	GERMINATION		DENSITY (TREES/FT <sup>2</sup> )	HEIGHT (cm)	DIAMETER (mm)	SHOOT WEIGHT (gm)
	PERCENT	RATE				
Surface	<sup>1</sup> 60.7 ab	32.4 a	26.7 ab	14.0 a	3.22 ab	1.30 a
1/4 inch	65.8 a	32.0 a	31.5 a	14.1 a	3.26 a	1.30 a
1/2 inch	52.5 b	32.1 a	23.5 b	12.5 b	3.09 b	1.14 b

<sup>1</sup> Values with the same letter within each variable are not significantly different at  $p=0.05$ .



Oven-dry shoot weight, 1+0 shoot height, and August soil temperatures were also significantly influenced by mulch treatments (fig. 3). The warmest August soil temperatures were associated with sand and control which produced the smallest 1+0 heights and shoot weights. The greatest 1+0 shoot heights and weights were produced by hydromulch and sawdust mulches which had the coolest August soil temperatures.



\* August soil T°C (1/4 in. depth)

□ - Shoot Height

▨ - Shoot Weight

Figure 3.--1+0 shoot height and 1+0 shoot weight for five mulch treatments; SND-Sand, HDM-Hydro-mulch, FAS-Fresh alder sawdust, CAS-Composted alder sawdust and C-Control (no mulch). Values with the same letter within each variable are not significantly different at  $p=0.05$ .

## CONCLUSIONS

Sowing depth and mulch are two factors that can be manipulated to improve germination, 1+0 seedling density, and growth of 1+0 Douglas-fir. The results of this study support the continued use of 1/8 to 1/4 inch sowing depths presently being used by most northwest nurseries. Generally, sowing Douglas-fir seed shallow is more advantageous than sowing deep.

Each nursery's soil and climatic conditions are unique and require special consideration when selecting a mulch material. For this study, mulching seedbeds with alder sawdust increased June soil temperatures which subsequently produced the best germination and seedling establishment relative to other mulches tested. Hydromulch treatments had the coldest June soil temperatures and the poorest germination and 1+0 seedling density. Later in the summer, alder sawdust provided the most favorable environment for seedling growth by producing the coolest August soil temperatures. Sawdust mulches consistently grew the largest 1+0 Douglas-fir seedlings. The sand and control plots, however, tended to have the warmest soil temperatures and grew the smallest 1+0 Douglas-fir. Northwest nursery conditions require mulch materials that

increase soil temperatures in order to improve germination and seedling establishment for early spring sowing. Later in the summer, the mulch should tend to decrease high soil temperatures in order to enhance seedling growth.

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## HERBICIDES FOR CONTROLLING WEEDS AT THE ALBUQUERQUE FOREST TREE NURSERY

L. J. Heidmann and Sally M. Haase

ABSTRACT: In 1982, a study was initiated at Albuquerque, New Mexico, to test oxyfluorfen, bifenox, and propazine for controlling grasses and forbs in ponderosa pine nursery beds. Propazine was highly toxic to pine seedlings. Oxyfluorfen at a rate of 0.5 pound ai per acre controlled vegetation without damage to tree seedlings.

## INTRODUCTION

Controlling unwanted vegetation is one of the many problems associated with managing a tree nursery. Grasses and forbs (weeds) begin to invade seedbeds shortly after sowing. Weeds may be controlled mechanically or chemically. Because of the closeness of the rows, however, seedbeds are difficult to cultivate. It is also difficult to eliminate weeds growing within the rows. Mechanical weeding, therefore, is usually limited to hand-weeding. To date, this has been the weed control method used at the Albuquerque Forest Tree Nursery in New Mexico.

If herbicides could accomplish the same job, the savings in time and money would be considerable. According to McDonald and Isaacson (1974), weeding costs may be reduced as much as 75% through the use of herbicides. In addition, seedling growth may be improved. In one nursery in Louisiana, two selective herbicides, applied as postemergent treatments to grasses, resulted in a 50% increase in plantable loblolly pine (*Pinus taeda* L.) compared to controls, even though the controls had been hand-weeded four times (South and Gjerstad 1982).

Herbicides, however, must control unwanted weeds without damaging tree seedlings. Certain herbicides such as trifluralin ( $\alpha, \alpha, \alpha$ -trifluoro-2,6-dinitro-N-N-dipropyl-p-toluidine) have produced toxic symptoms in loblolly pine seedlings at rates as low as 0.5 pound per acre (0.56 kg/ha) (Rowan 1978), although at the Norman nursery in Oklahoma trifluralin was incorporated at a rate of 0.75 pound ai per acre (0.84 kg/ha) several weeks before sowing without any harmful effects on seedlings (Abrahamson 1983). Ryker (1979a) found bifenox (methyl-5-(2,4-dichlorophenoxy)-2-nitrobenzoate) at rates of 3 to 6 pounds ai per acre

(3.36 to 6.72 kg/ha) was toxic to ponderosa pine (*Pinus ponderosa* var. *scopulorum*) seedlings at the nursery in Albuquerque.

## THE STUDY AREA

The Albuquerque nursery was established in 1977, and the first beds were sown in 1978. Soils are loamy sands and sandy loams. The soil pH now averages 7.6, a drop from a pH of 8.6 at the time of nursery establishment. Calcium carbonate levels are high, ranging from 2.3% to 11.3%, and average 5.9%. Soil organic matter content now averages 1.3%.

Some of the more commonly occurring grasses are sixweeks grama (*Bouteloua barbata*), sand dropseed (*Sporobolus cryptandrus*), stinkgrass (*Eragrostis cilianensis*), Bermudagrass (*Cynodon dactylon*), and fall witchgrass (*Leptoloma cognatum*). Forbs include Russian thistle (*Salsola kali*), oakleaf datura (*Datura quercifolia*), prostrate pigweed (*Amaranthus blitoides*), puncturevine (*Tribulus terrestris*), and tanseymustard (*Descurainia pinnata*).

## THE STUDY, 1982

In 1982, a study was initiated at Albuquerque to test the effectiveness of bifenox, oxyfluorfen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene), and propazine (2-chloro-4,6-bis(isopropylamino)-s-triazine) in controlling weeds in ponderosa pine nursery beds. Bifenox and oxyfluorfen are registered for forest nursery use and have proven effective and safe on ponderosa pine in other western nurseries (Stewart 1977; Ryker 1979b). Heidmann (1970) found that propazine could be applied to planted ponderosa pine nursery stock on basalt-derived soils at rates up to 10 pounds ai per acre (11.20 kg/ha) without damage to the seedlings. The decision was made to test bifenox at Albuquerque again because of the changes (pH and organic matter content) in the soils since Ryker's (1979a) work was conducted.

## Methods

The three herbicides--bifenox, oxyfluorfen, and propazine--were applied at various rates and times in four randomized blocks. Each block consisted of 12 plots, each 25 feet (7.62 m) by 4 feet (1.22 m). Each plot was a section of nursery bed in normal seedling production. A 10-foot (3-m) buffer was left between plots within the same nursery bed. Each plot was randomly assigned one of the treatments listed in table 1. Treatments

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Table 1.--Effects of herbicide treatments applied to study plots at Albuquerque Forest Tree Nursery in 1982

Treatment	Time of application <sup>1</sup>	Rate		Tree density <sup>2</sup>	Mean oven-dry weights <sup>3</sup>	
					Tops	Roots
		pounds		Mean	- - - - - gram - - - - -	
		<u>ai/acre</u>	(kg/ha)	<u>no./ft</u> <sup>4</sup>		
1. Untreated (control)				14.6 c <sup>4</sup>	0.1846 bcd <sup>4</sup>	0.1397 de <sup>4</sup>
2. Bifenox	ps	1.5	(1.68)	11.3 b	.1297 ab	.1103 c
3. Bifenox	ps +	1.5	(1.68)	9.9 b	.1662 abc	.1264 cd
	pg (6 weeks)	1.5	(1.68)			
4. Propazine	ps	1.5	(1.68)	0.0	.0000	.0000
5. Propazine	ps +	1.5	(1.68)	0.0	.0000	.0000
	pg (6 weeks)	1.5	(1.68)			
6. Oxyfluorfen	ps	0.5	(0.56)	9.0 b	.1301 ab	.0851 ab
7. Oxyfluorfen	ps	1.0	(1.12)	2.8 a	.1159 ab	.0658 a
8. Oxyfluorfen	ps	1.5	(1.68)	2.4 a	.1005 a	.0893 b
9. Oxyfluorfen	pg (6 weeks)	0.5	(0.56)	15.7 cd	.1733 abc	.1623 f
10. Oxyfluorfen	pg (6 weeks)	1.0	(1.12)	16.1 cd	.2475 d	.1683 f
11. Oxyfluorfen	pg (6 weeks)	1.5	(1.68)	16.5 d	.2239 cd	.1469 ef
12. Oxyfluorfen	ps +	0.5	(0.56)	10.0 b	.1577 abc	.1110 c
	pg (6 weeks) +	0.5	(0.56)			
	pg (12 weeks)	0.5	(0.56)			

Treatments 3, 5, and 12 were applied both after seeding and after germination at the indicated rates and times.

<sup>1</sup>Key to applications:

ps--herbicide was applied at the rate indicated within 48 hours after beds were sown.

pg--herbicide was applied at the rate indicated 6 weeks or 12 weeks after beds were sown, i.e., after germination.

<sup>2</sup>Mean number of trees in 36 sample rows, 1 foot in length.

<sup>3</sup>Means based on 12 samples of 10 trees.

<sup>4</sup>Means with the same letter are not significantly different at the 0.05 level as determined by Waller-Duncan multiple comparison test.

were applied within 48 hours of seeding (postseeding), 6 and 12 weeks after seeding (postgermination), or as a combination of both (table 1). The postseeding and postgermination treatments were selected to compare effectiveness of one treatment at time of sowing with one or two followup treatments. Oxyfluorfen was used more often for postgermination treatments because of its effectiveness as a postemergence treatment. The beds were sown with ponderosa pine seeds on May 26. Herbicides were applied in water at a rate of 40 gallons (151.4 l) of solution per acre, using a 3-gallon (11.36 l) hand-powered backpack sprayer. After application, beds were watered for 20 minutes, three times a day, until germination started.

#### Measurements

Grass and Forbs.--Within each plot, five permanent sample plots, 1 foot (0.30 m) square, were located down the center of each plot. Each of the five plots was randomly located within a 5-foot (1.52-m) section of the main plot and marked with wire flags. In each of the sample plots, the number of grasses and forbs was counted 6, 12, and 20 weeks after sowing of pine seed.

Phytotoxicity.--Herbicide damage to pine seedlings was determined in three sample plots, (1 by 4 feet) (0.30 by 1.22 m) randomly located across the beds in each treatment plot. Vigor of pine seedlings

was estimated at 6, 12, and 20 weeks using a system proposed by Anderson (1963). In addition, all seedlings in three randomly selected rows within the tree vigor sample plot were counted. The two outside rows were used as a buffer and were excluded from the count. In the fall, 30 seedlings, 10 from each sample plot, were lifted for determining oven-dry (OD) weights of the tops and roots. Appropriate means were obtained by analysis of variance, and differences were determined by using Waller-Duncan's multiple comparison test.

#### Results

In 1982, weed control measurements were compromised when nursery personnel inadvertently weeded the study plots. However, information on seedling toxicity was collected. It became evident soon after seedlings began to germinate that the propazine treatments were toxic. Most of the propazine plots had no live trees a few weeks after treatment. Therefore, all propazine treatments were excluded from analysis. It was also difficult to assign vigor ratings to seedlings since general chlorosis of seedlings at Albuquerque is a common problem. Because of this, only number of trees per linear foot and OD weights of tops and roots were analyzed.

A significant loss of seedlings was caused also by oxyfluorfen applied postseeding at all rates

( $P=0.05$ ). There were less than three seedlings per linear foot for two of these treatments, compared to 14.6 for controls (table 1). The other treatments, except postgermination applications of oxyfluorfen, had similar results. Oxyfluorfen applied after seeding at 1.5 pounds ai per acre (1.68 kg/ha) produced top OD weights significantly lower than the control (table 1,  $P=0.05$ ). Root OD weights were not different from the control for bifenox applied postseeding plus postgermination and for oxyfluorfen at 1.5 pounds ai per acre (1.68 kg/ha) applied postgermination. Postseeding application of oxyfluorfen and the remaining bifenox treatment reduced root OD weights significantly. Postgermination application of oxyfluorfen at 0.5 and 1.0 pound ai per acre (0.56 and 1.12 kg/ha) increased root OD weight (table 1).

#### THE STUDY, 1983

The study was repeated in 1983 because no weed control information could be collected in 1982. Since propazine and postseeding rates of oxyfluorfen resulted in significant reduction of seedling numbers, these treatments, except for the lowest rate of oxyfluorfen, were eliminated. The treatments listed in table 2 were applied in the same manner as in 1982, and the experiment was conducted in the same way, except that the five sample plots in each main plot on which grasses and forbs were counted, were increased in size from 1 square foot ( $0.09 \text{ m}^2$ ) to 4 square feet ( $0.37 \text{ m}^2$ —0.30 by 1.22 m, across the bed).

#### Results

In general, postseeding application of herbicides provided the greatest control (table 2). All treatments, except oxyfluorfen applied after germination, reduced grass and forb cover significantly ( $P=0.05$ ). There was no vegetation present on plots treated with oxyfluorfen postseeding plus postgermination, while the postseeding rate of 0.5 pound ai per acre (0.56 kg/ha) had only 0.05 plant per sample plot. Both of these treatments completely controlled grasses. Bifenox at 1.5 pounds ai per acre (1.68 kg/ha) and oxyfluorfen, applied after germination, were not effective in reducing grasses. All treatments had significantly fewer forbs than the control.

There were no toxic effects of the herbicides noted in 1983. The number of trees per linear foot did not differ by treatment (table 2). Oven-dry weights of seedling tops, however, were significantly different (table 2,  $P=0.05$ ). Oxyfluorfen applied postseeding and postseeding plus postgermination at 0.5 pound ai per acre (0.56 kg/ha) and bifenox applied postseeding at all rates produced tops heavier than the control. Root weights for these treatments and for oxyfluorfen applied postgermination at 1.5 pounds ai per acre (1.68 kg/ha) were also significantly heavier than the control (table 2,  $P=0.05$ ).

Table 2.--Effects of herbicide treatments applied to study plots at Albuquerque Forest Tree Nursery in 1983

Treatment	Time of application <sup>1</sup>	Rate	Tree density <sup>2</sup>	Vegetation <sup>3</sup>			Mean oven-dry weights <sup>4</sup>	
				Forbs	Grass	Total	Tops	Roots
		pounds ai/acre (kg/ha)	Mean no./ft	gram				
1. Untreated (control)			19.2	1.7 e <sup>5</sup>	6.60 de <sup>5</sup>	8.30 e <sup>5</sup>	0.0753 a <sup>5</sup>	0.0490 a <sup>5</sup>
2. Bifenox	ps	0.5 (0.56)	21.9	0.05 ab	0.45 a	0.50 a	.1190 bc	.0857 cd
3. Bifenox	ps	1.0 (1.12)	27.0	0.05 ab	0.10 a	0.15 a	.1637 de	.1096 e
4. Bifenox	ps	1.5 (1.68)	23.0	0.25 b	0.05 a	0.30 a	.1543 cde	.1043 de
5. Bifenox	pg (6 weeks)	0.5 (0.56)	22.2	0.95 d	4.05 bc	5.00 bc	.0814 a	.0583 ab
6. Bifenox	pg (6 weeks)	1.0 (1.12)	22.8	0.65 c	4.05 b	4.70 b	.0816 a	.0653 abc
7. Bifenox	pg (6 weeks)	1.5 (1.68)	20.2	0.25 b	5.30 cd	5.50 bcd	.0859 ab	.0594 ab
8. Oxyfluorfen	ps	0.5 (0.56)	27.8	0.05 ab	0.00 a	0.05 a	.1371 cd	.1040 de
9. Oxyfluorfen	pg (6 weeks)	0.5 (0.56)	22.6	0.00 a	8.15 e	8.15 e	.0655 a	.0479 a
10. Oxyfluorfen	pg (6 weeks)	1.0 (1.12)	23.4	0.00 a	6.50 de	6.50 cde	.0784 a	.0481 a
11. Oxyfluorfen	pg (6 weeks)	1.5 (1.68)	21.0	0.10 ab	7.35 e	7.45 de	.1003 ab	.0752 bc
12. Oxyfluorfen	ps + pg (6 weeks)	0.5 (0.56) 0.5 (0.56)	23.9	0.00 a	0.00 a	0.00 a	.1793 e	.1154 e

Treatment 12, oxyfluorfen, was applied after seeding and after germination at the indicated rates and times.

<sup>1</sup>Key to applications:

ps--herbicide was applied at the rate indicated within 48 hours after beds were sown.

<sup>2</sup>pg--herbicide was applied at the rate indicated 6 weeks after beds were sown; i.e., after germination.

<sup>3</sup>Mean number of trees in 36 sample rows, 1 foot in length.

<sup>4</sup>Numbers are means of 20 sample plots, 1 by 4 feet.

<sup>5</sup>Mean based on 12 samples of 10 trees.

<sup>6</sup>Means with the same letter are not significantly different at the 0.05 level as determined by Waller-Duncan multiple comparison test.



## DISCUSSION AND CONCLUSIONS

Oxyfluorfen and bifenox at fairly low rates effectively controlled grasses and forbs in tests at the Albuquerque Forest Tree Nursery when applied after seeding. Oxyfluorfen applied postseeding plus postgermination gave the best results. None of the herbicides at rates tested in 1983 was toxic to ponderosa pine seedlings. In 1982, however, all treatments except oxyfluorfen applied postgermination significantly reduced seedling numbers. Treatments that obviously controlled competing vegetation generally produced larger pine seedlings, presumably because of more available moisture.

Because in this study oxyfluorfen gave variable results, a fact also observed by Ryker (1984), it is suggested that this herbicide be used on a limited basis at the Albuquerque nursery until more definitive results are obtained. Bifenox at postseeding rates up to 1.5 pounds ai per acre (1.68 kg/ha) might also be tested.

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# GERMINATION OF WESTERN WHITE PINE SEED //

Patricia L. Malone

ABSTRACT: Two series of germination tests were conducted to compare different stratification techniques for western white pine seed. The first series of tests compared stratification in moist peat moss, naked stratification, and stratification on media in Ray Leach pine cells. The second series of tests added a fourth treatment involving a chlorine soak. Stratification in pine cells yielded the most promising results in both trials.

## INTRODUCTION

Western white pine (*Pinus monticola* Dougl.) is one of the most productive timber species in the Inland Empire. In northern Idaho and western Montana, western white pine is planted for reforestation of federal, state, and private lands. In 1968, the Northern Region of the Forest Service discontinued planting of western white pine due to the devastating effects of the pathogen *Cronartium ribicola* Fisch., white pine blister rust. But tree improvement research has since led to development of western white pine seed sources which are resistant to blister rust. The majority of the resistant seed is produced in three seed orchards located in Idaho. The white pine cooperators in the Inland Empire Tree Improvement Cooperative have established additional seed orchards, but most are not yet producing seed, and cone and seed insects in the three producing orchards are seriously reducing yields. Furthermore, as the orchard yields decrease, the demand for western white pine planting stock is increasing (table 1). So, western white pine seed is not only very valuable in terms of the research that has gone into the production of improved seed, but it is also in high demand and short supply. This situation makes it essential for the grower to come as close as possible to the "one seed per seedling" ideal.

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Table 1.--Western white pine grown at Coeur d'Alene Nursery, 1982-1986

Bareroot		Container	
Date to ship	Thousands	Date to ship	Thousands
Spring 82	362	Fall 82	394
Spring 83	629	Spring 83	101
Spring 84	666	Fall 83	370
Spring 85	<sup>1</sup> 1014	Spring 84	<sup>3</sup> 482
Spring 86	<sup>2</sup> 635	Fall 84	<sup>4</sup> 269
		Spring 85	27

- <sup>1</sup> Total request from Region 1 Forests
- <sup>2</sup> Adjusted request to account for seed shortages (original request 1MM +)
- <sup>3</sup> Adjusted request to account for seed shortages (original request 294 M)
- <sup>4</sup> Adjusted request to account for seed shortages (original request 259M)

Two problems which plague the western pine grower are 1) the lack of consistent, high correlation between laboratory germination tests and operational sowings, and 2) the length of time over which new germination will occur. The first problem causes many growers to oversow white pine more than other species to guarantee that they will meet requests. The second problem, the tendency of western white pine to delay germination until the second season after sowing, results in non-uniform seedbed densities and heavy culling during the grading operation. Both situations make less than optimal use of the small amount of available seed.

Numerous trials have been conducted with both eastern and western white pines to develop a presowing treatment that would consistently give rapid, uniform germination. Wahlenberg (1924) advocated fall sowing of western white pine to avoid what he called the "hold-over characteristic," the tendency of the five-needled pines to not germinate all their viable seed the first season after spring sowing. Larsen (1925) believed that the delayed germination was caused by the presence of an impermeable seed coat, and suggested various stratification techniques, chemical and mechanical scarification, and exposure to freezing temperatures, as solutions. Studies with eastern white pine seed tested the value of



plant growth regulators (Kozlowski 1962a) and other chemicals (Kozlowski 1962b). The responses of eastern white pine seed to light (Toole and others 1962), and western white pine to infrared irradiation (Works and Boyd 1972) have been tested, as have the effects of an oxygen-enriched stratification environment (Kidd 1982). Some of these techniques have been successful, and some have not, but none has given satisfactory results with each repetition.

In the past three years, the Coeur d'Alene Nursery has conducted a number of administrative studies and operational sowing trials with western white pine seed, comparing different stratification treatments and durations. The objective of these trials has been to develop a pre-sowing treatment for this species that gives consistent, rapid germination, and yields the maximum number of seedlings per unit of viable seed.

This paper presents the results of two series of germination tests conducted by the seed laboratory at the Coeur d'Alene Nursery.

#### 1983 WESTERN WHITE PINE STUDY

##### Methods

The first series of germination tests consisted of three treatments and nine seed lots. The seed lots were all collected in 1980, they had all been in freezer storage at 0° F (-18° C), and they had all been tested previously (table 2). The three treatments consisted of 1) stratification in moist peat moss (Peat), 2) naked stratification (Naked), and 3) stratification on premixed growing media in pine cell containers (Container). Each stratification treatment was initiated following a 48-hour running water soak. Stratification was 100 days at 34° to 36° F (1° to 2° C).

Treatment #1, Peat.--At the time of this test, stratification in peat moss was the normal operating procedure for western white pine at the Coeur d'Alene Nursery. This treatment may therefore be considered the control (the previous tests for each of the nine seed lots had been stratified in this manner). Following the 48-hour soak, the seed, in nylon mesh bags, was buried between two layers of moist peat moss. The peat moss was moist enough that water could be squeezed out without difficulty. The tray containing the peat was put into a plastic bag and closed loosely with a twist tie. At 3-week intervals the seed was uncovered, the mesh bags dipped in water to maintain a surface film of moisture on the seed, and reburied in the peat.

Treatment #2, Naked.--Following the 48-hour soak, the mesh bags (one per seed lot) were placed in plastic bags and loosely closed with twist ties. The bags were removed from stratification once a week and soaked for 1 hour in running water. They were then reinserted in the plastic bags, and put back into the stratification room.

Treatment #3, Container.--Following the 48-hour soak, the seeds were hand sown on pine cells filled with the standard, 50% peat/50% vermiculite growing media used in the Coeur d'Alene greenhouses. The seeds were covered with a thin layer of perlite, and watered until water ran out of the bottoms of the containers. The trays (200 cells each) were placed inside large trash bags and put in the stratification room.

Following the 100-day stratification period, the peat and naked treatments were removed from the stratification room, and the seed spread on paper towelling to surface dry. The seed was sown with a vacuum counter in square plastic germination dishes; the media used was kimpak, moistened with tap water. Each treatment was repeated four times for each seed lot (four replications of 100 seeds, each germination dish being one replication). The germ dishes were placed in the germinator, which was set at the standard temperature regime, 8 hours at 86° F (30° C) with light, 16 hours at 68° F (20° C) in darkness. Counts were made at 7-day intervals for 28 days.

On the same day that the peat and naked treatments were put in the germinator, the container treatment was moved from the stratification room to the small glass greenhouse. Each seed lot had two trays of 200 containers each (four replications of 100 seeds). The trays were arranged randomly on the bench, and the temperature was set to maintain about 70° F (21° C). Bottom heat was not used, and the bench was directly against the glass. Counts were made at 7-day intervals for 28 days.

##### Results

Table 2.--1983 western white pine germination

SEED LOT	NO. DAYS	28-DAY GERMINATION %			PREVIOUS TEST	
ID	STRAT	PEAT	NAKED	CONT	DATE	GERM %
3379	100	85	83	93	81	87
4305	100	85	82	97	81	86
4611	100	65	37	79	81	79
4612	100	82	83	83	81	54
4613	100	60	55	81	81	73
4616	100	70	70	92	81	62
4621	100	44	34	73	81	77
4622	100	57	59	84	81	63
4654	100	22	9	64	81	44

## Methods

The test conducted in 1984 was similar to the 1983 test except there were fewer seed lots (six) and one additional treatment (table 3).

Treatment #1, Peat.--This treatment was the same as in the 1983 test.

Treatment #2, Naked.--This treatment was the same as in the 1983 test.

Treatment #3, Container.--This treatment was the same as in the 1983 test with one exception: The small glass greenhouse was not kept as warm during this study. Because of the slow response of the seed the first two counts (two weeks), one additional count was taken on day 35.

Treatment #4, U of I.--The "University of Idaho" treatment was developed by Benny Advincula, Art Partridge, and John Woo. The method is explained in detail in the Coeur d'Alene Nursery's 1983 Annual Report. The seed was soaked for 10 minutes in a solution of two parts bleach, three parts tap water. It was then washed in running water for 4 days. The seed (still in mesh bags) was wrapped in wet paper towelling, and each seed lot was placed in a plastic bag. The seed was stratified in the stratification room with the other treatments, but for only 45 days, instead of 100 days.

## Results

Table 3.--1984 western white pine germination

SEED LOT ID	NO. DAYS STRAT	28-DAY GERMINATION %				PREVIOUS TEST	
		PEAT	NAKED	CONT	U OF I	DATE	GERM%
4779C	100	41	75	87		83	50
	45				83		
4779I	100	43	71	90		82	45
	45				78		
4779K	100	60	66	84		82	40
	45				76		
4780I	100	60	60	90		82	57
	45				84		
4684C	100	44	61	96		82	67
	45				79		
2044L	100	59	70	86		82	57
	45				77		

## DISCUSSION

The first observation to be made from these tests is that the western white pine seed lots germinated better when stratified in containers than when stratified by any of the other methods. In general, the University of Idaho treatment was the second best treatment. The most striking observation to be made from the peat moss and naked stratification treatments in both studies is that they consistently resulted in much poorer performance than the container and U of I treatments. With a few exceptions, there did not appear to be a marked difference between the peat and naked treatments.

There are a number of possible explanations for these results. The superior performance of the seed stratified in containers may result from the individual environment in which each seed was stratified. If there are water-soluble inhibitors within the seed, this method would preclude them from affecting adjacent seeds. The concentration of oxygen may also be higher around the individual seed under a thin layer of perlite, than in the center of a mesh bag containing 500 seeds. It is also possible that the temperature of the greenhouse in which the containers were germinated was more favorable than the higher temperatures of the germinator.

The University of Idaho treatment is significant in that it resulted in germination percentages nearly as high as those of the container treatment, and in less than half the stratification time. This treatment destroys mold spores on the surface of the seed coat, and its developers feel it may also affect the physical structure of the seed coat.

It does not appear that genetic differences are reflected in these results. The mixture of seed lots used for the two studies contains seed from both seed orchards and seed production areas (open-pollinated wild stands that have been rogued and managed for seed production). We do know from tree improvement research that individual families behave very differently in terms of germination rate and percent, but all the seed lots tested here reacted similarly.

The obvious problem with the container method is that it cannot be used in a bareroot operation, and takes considerable cooler space to implement for a container operation. The University of Idaho method has not given totally consistent results when repeated, but is much easier to implement on an operational scale. Both treatments appear more promising than the traditional peat or naked stratification methods.



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## POST-PLANT CONTROL OF NEMATODES IN BAREROOT NURSERIES

F.D. McElroy

**ABSTRACT:** The effect of fenamiphos (Nemacur) on Pratylenchus penetrans under Douglas-fir seedlings was evaluated in a Washington State transplant nursery. Optimum nematode control was obtained using 6 lb ai/a. Nematodes in the roots were reduced by almost 88 percent, and in the soil by 90 percent fifteen weeks after treatment. Nemacur at 3 and 6 lb ai/a increased seedling height by 15 and 23 percent respectively, and root weight by 38 and 43 percent respectively over untreated seedlings. These treatments had little effect on mycorrhizae development.

## INTRODUCTION

The root-lesion nematode, Pratylenchus penetrans, can cause considerable damage to young conifer seedlings in forest nurseries (Ruehle 1975). Direct damage caused by feeding of the nematode results in a decreased and rotted root system, with a significant lack of fine feeder roots. Frequently, heavily infected roots have a witches-broom symptom resulting from proliferation of short roots. Indirectly, the nematode appears to affect the development of mycorrhizae on the roots (unpublished data). All of this root damage results in above ground growth that is stunted and chlorotic.

There are several preplant nematicides which effectively control this nematode, but to date, no postplant treatments have been available to the nurseryman. This is a report on the use of fenamiphos (Nemacur) applied after the planting of Douglas-fir seedlings to control Pratylenchus penetrans.

## MATERIALS AND METHODS

Tests were carried out at a transplant nursery near Bow, Washington. This is a relatively young nursery, which had previously been cropped to grain for a number of years. As a result, a rather large population of Pratylenchus penetrans built up to the point where conifer seedling growth was affected.

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Plot establishment.--Two-year-old Douglas-fir seedlings obtained from another bare-root nursery were planted into the test site on 11 April 1983 using standard transplanting procedures. Application of Nemacur was delayed until mid-June to allow for completion of transplanting operations and for development of root activity.

On 14 June 1983 Nemacur 3 was applied at 0, 3, 6, and 12 lb ai/a. Nalco-trol at 6-ounces per 150-gallons of water was mixed with each treatment as an adjuvant. Within 24 hours after application of the Nemacur, one inch of water was applied through a fixed line overhead irrigation system to move the chemical into the root zone. Each treatment consisted of three 4-foot beds containing six rows of seedlings 1,000-feet long, with the exception of the 12-pound rate, which was only 25-feet long. The latter rate was for determination of phytotoxicity only.

Six plots 4 X 30 feet were established for each treatment. Two soil textures were present in the 1,000-foot of bed, a fine sandy loam on the west half, and a loam on the east half. Three of the six plots per treatment were established on each soil texture.

Nematode evaluation.--Nematode samples were collected postplant, pretreatment on 16 May, and 15 weeks after treatment on 28 September. Twenty 1 X 8-inch soil cores were taken from the center four rows of each plot at each sampling time. On 28 September five seedlings were dug at random from the center four rows of each plot for growth analysis and nematode extraction from the roots. All samples were transported to the lab in poly bags in a cooler. Nematodes were extracted from the soil using the centrifugal-flotation technique and from the roots by misting for 72 hours.

Growth evaluation.--The height (soil line to terminal bud) of ten seedlings within each plot was measured in the nursery. Caliper, weight of mycorrhizal and non-mycorrhizal roots, and total root weight was determined for the five dug seedlings per plot.

## RESULTS AND DISCUSSION

Effect of Nemacur on nematode numbers.--The effect of Nemacur on P. penetrans under Douglas fir seedlings is shown in tables



Table 1.-- The effect of fenamiphos on numbers of Pratylenchus penetrans in soil under Douglas-fir

Rate	Pratylenchus/pint of soil		% Decrease
	Pretreat	Posttreat	
0 gpa	1316.7	1083.3	17.7
1	2491.2	666.7	73.3
2	2320.8	225.0	90.3
4	1275.0	100.0	92.0

Table 2.-- The effect of fenamiphos on numbers of Pratylenchus penetrans in the roots of Douglas-fir

Rate	Pratylenchus/gram of root			% of CK
	+Mycor	-Mycor	Total	
0 gpa	349.1	421.2	235.8	-
1	162.0	150.5	126.2	46.4
2	26.0	37.6	28.8	87.8
4	0.9	4.3	2.6	98.8

+Mycor = mycorrhizal roots; -Mycor = non-mycorrhizal roots.

1 and 2. Optimum control was obtained with the 6 lb ai/a rate. Nematodes in the roots were reduced by almost 88 percent and in the soil by 90 percent fifteen weeks after treatment. The lower rate resulted in survival of significantly more nematodes in both soil and roots. While the highest rate was represented by only one plot, nematode control in the roots was almost 100 percent.

Because of the mode of action of this nematicide, i.e. prevention of feeding and reproduction of the nematode, populations may have continued to decline beyond the fifteen week period, and may have even been lower by seedling lifting time in December and January. A greater reduction in numbers may also have been obtained by applying the nematicide closer to planting time, as the chemical was applied here eight weeks after planting.

Previous observations at this and other nurseries indicated that P. penetrans prevented the development of mycorrhizae on the roots of conifer seedlings. However, no differences could be detected in this test. While populations of nematodes were generally lower in the mycorrhizal roots, differences were not significant due to the amount of variability. A different type of test is needed to determine this effect.

Table 3 shows the effect of soil texture on nematode populations. Populations were consistently higher in the loam than in the fine sandy loam soils. However, soil type appeared to have little effect on control by Nemacur. Numbers were reduced by similar amounts in both soil types.

Effect of Nemacur on seedling growth.--  
Nemacur at 3 and 6 lb ai/a increased seedling height by 15 percent and 23 percent

Table 3.-- The influence of soil type on control of Pratylenchus penetrans by fenamiphos

Rate	Type	Soil (#/pt)		% Change	Roots (#/g)
		Pre	Post		
0 gpa	SL	400.0	891.7	+55.1	84.1
	L	2233.3	1275.0	-42.9	387.5
1	SL	1208.3	258.3	-78.8	36.3
	L	3775.5	1075.0	-71.5	216.1
2	SL	916.7	175.0	-80.9	14.3
	L	3725.0	275.0	-92.6	43.5

SL = sandy loam; L = loam.

Table 4.-- The effect of fanamiphos on growth of two-year-old Douglas-fir seedlings

Rate	Ht	Caliper	Root Weight (grams)		Total
			+Mycor	-Mycor	
0 gpa	62.2	10.6	2.039	6.513	8.554
1	73.4	11.5	3.959	9.771	13.754
2	80.0	10.7	3.859	11.139	15.000

Ht = height in cm; Caliper = diameter in cm of the stem at the root collar;  
+Mycor = mycorrhizal roots; -Mycor = non-mycorrhizal roots.

respectively, and root weight by 38 percent and 43 percent respectively over untreated seedlings (table 4). There was little difference in the percent of mycorrhizal roots (65-68 percent) in any of the treatments. Caliper was also unaffected by treatment.

#### CONCLUSIONS

The results of these tests show that Nematicur is an effective postplant nematicide for controlling P. penetrans in forest nurseries.

It not only is effective in reducing nematode populations in the soil and roots, but also increases root production and seedling height.

Nematicur offers several advantages for use in forest nurseries:

1. Application of the nematicide after transplanting is complete prevents exposure of transplanting personnel to the chemical;

2. The postplant treatment provides for control of nematodes which might be introduced into a transplant nursery with planting stock;
3. Unexpected nematode problems in young stock can be corrected without loss if diagnosed early;
4. Nematode problems can be corrected in a proposed planting block where rotation schedules do not allow for preplant fumigation;
5. This nematicide has no harmful effect on mycorrhizae development on seedling roots;
6. Applied as a bed treatment it is less expensive than a preplant fumigation.

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SOIL PEST MANAGEMENT PROGRAMS FOR BAREROOT NURSERIES

F.D. McElroy

**ABSTRACT:** The most numerous and economically important pest problems facing bareroot nurserymen in the Pacific Northwest are soilborne. Several soilborne fungus, insect, and nematode species attack conifer seedlings causing economic loss. Control of these organisms is expensive and the use of extreme measures, such as biocidal fumigants, has an adverse effect on beneficial soil organisms. This in turn affects seedling growth and quality. A program for determining the presence and disease causing potential of these pests and their management is discussed.

#### INTRODUCTION

Thirteen diseases or disease groups are listed by Sutherland in the recently published Forest Nursery Manual (Sutherland 1984). Eight of those are soilborne, and represent the most economically important diseases. Four of the seven insects listed are also soilborne, and at least three nematode species are known to cause economic loss in bareroot nurseries. Many of the weed problems experienced by bareroot nurserymen are also resident in the soil.

In U.S. Northwest nurseries, soil fumigation with methyl bromide-chloropicrin (M-C) is the most widely used control measure for these organisms. This material while very effective against all of the organisms mentioned is extremely expensive, costing approximately \$1200 per acre. Treatment of the soil with M-C also has several adverse side effects. If applied improperly or under unfavorable environmental circumstances it can result in damage to the seedlings. Under some soil conditions stunting of the seedlings is also frequently observed following fumigation. This is believed to be the result of a loss of mycorrhizae and other beneficial soilborne organisms. Another result of the use of this material is the creation of a "biological vacuum". This is a situation in which all microorganisms are eliminated from the soil. As a result the first

organism to return to that soil, usually a pathogen, has no antagonists to compete with and usually builds quite rapidly to very high levels.

#### SOIL MONITORING

In British Columbia, Canada, the Pacific Forest Research Center in Victoria monitors the soil fungus populations in all of the government owned bareroot nurseries in B.C. Pythium and Fusarium assays of the soil are made annually for each block to be sown. An effective formulation of M-C is not presently registered for use in Canada so this is not an option where high fungal populations are found. Instead, a summer bare-fallow program which reduces pathogen levels is recommended in these circumstances.

The Washington State Department of Natural Resources Nursery (Webster Nursery) in Olympia, Washington, operates a similar program. However, since M-C fumigation is registered for use in Washington it is recommended for control of high levels of soil fungi.

Peninsu-Lab has adapted and modified these programs to make them available to bareroot nurserymen in the Northwest. We currently assay soils for Fusarium, Pythium, Phytophthora, and Nematodes. Based on the kinds and numbers of organisms found, a recommendation regarding the need for fumigation is made. If no pathogenic fungi and nematodes are found, or if they are found at low levels, alternatives to M-C fumigation are suggested. Because of climatic and management variation between nurseries, the non-fumigation option is usually recommended for only a portion of the nursery during the first couple years of testing to establish disease threshold levels for that nursery. This program has been successfully tried in several nurseries with a considerable savings in fumigation costs and an increase in seedling quality.

The relative importance of these soil organisms depends upon the crop to be grown. Therefore, separate monitoring programs are set up for sowing and transplant blocks within the nursery.

#### Sowing Blocks

Fusarium, Pythium, and sometimes Phytophthora are important fungi attacking first-year

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conifer seedlings and are analyzed for routinely. If other soil fungi are known to be a problem in the nursery, such as *Macrophomina*, a special analysis may be requested. Nematodes found to be causing damage to conifer seedlings in the Northwest and assayed for are *Pratylenchus*, *Xiphinema*, and *Trichodorus*.

The results of the laboratory analysis indicate the population level of organisms found. This in combination with cropping history, disease incidence, and other background data from the nursery is used to make a recommendation regarding the need for fumigation. If fumigation is necessary, then a follow-up sample is run to ensure its effectiveness. Follow-up soil and seedling disease assays are used to confirm the predictive assays and to establish threshold damage levels for each nursery. Soil fungus population assays from diseased and healthy areas during the first year of seedling establishment help to identify damaging threshold levels.

Adequate procedures for predictive sampling of soilborne insects have not been established as yet. Cropping history is the best indicator presently. However, during the first two years trapping in the sowing block for the cranberry girdler and root weevil can be used to predict population levels so that preventative control measures may be taken.

#### Transplant Blocks

Transplant blocks can be managed differently since the seedlings are older and less susceptible to a wide range of fungi. Here the fungi of concern are those causing root-rot, such as *Pythium* and *Phytophthora*. A soil fungus assay for *Pythium* and *Phytophthora*, along with cropping and disease history, dictate a management decision to deal with these. Sometimes block renovation or repeated between-bed subsoiling can be used to promote good drainage and lessen the chance of fungus infection. In severe cases chemical treatment may be necessary to control the root-rot organisms.

Because transplant blocks are less intensively managed nematode problems tend to occur here. Seedlings with limited root systems, such as 1-1's and plug 1's, are especially susceptible to nematode damage. Routine assays can determine potential problem areas and pre- or post-plant nematicides can be applied to correct the problem. Some nematode species such as *Xiphinema bakeri* can be controlled through summer bare fallow. Other nematode species which feed inside root systems require chemical treatment for control.

Insect damage to transplants is usually less frequent than damage to one and two year old seedlings. However, in areas

with high insect populations, they can cause considerable damage. Again, trapping for the cranberry girdler and root weevil is an effective means of predicting potential damage areas. Cropping and damage history is also important.

#### ASSESSMENT

##### Sampling Procedures

The most reliable and useful sampling technique is the one presently used by the Webster Nursery (Russell 1976). In this procedure three separate samples are collected for each pipeline in the sowing block. A separate analysis is run on each sample and the results are plotted on the block map. Isolines can then be drawn around the different levels of soil fungi, and problem areas can be located.

We have tested several different types of sampling procedures to determine the most dependable and least costly. While the Webster Nursery technique is the most reliable and most effective means of predicting damage areas within a block, it is also the most costly. At current laboratory prices this would run over \$500 an acre. The next most effective sampling technique is to take a composite of soil cores from a two-acre unit and run a single analysis on those. While this does not give as much information regarding distribution of soil organisms, it still enables prediction of problem areas at a cost of less than 1/10 of the previous technique.

It is important that each two-acre unit represent the same soil type and cropping history, as this will affect soil organism populations. Different soil types and cropping history should be sampled separately.

##### Sampling Time

If bare summer fallow is a management option, samples may be taken in March or April. During the summer the soil should be worked several times to reduce weed populations and bring deeper soil to the surface for drying. In September a sample taken from the area of highest organism count should be analyzed to indicate effectiveness of the fallow or need for fumigation.

If bare summer fallow is not an option, samples should be taken in September after the cover crop has been plowed down and the soil worked. If results indicate fumigation is necessary, a post-fumigation sample should be taken no sooner than one month after fumigation and as late as March the following year. This will determine the effectiveness of fumigation or the need of further treatment.



For blocks to be fall transplanted, samples should be taken in the spring to allow time for proper management procedures. For spring transplants, a fall sampling is necessary.

#### MANAGEMENT OPTIONS

Presently the number of management options available to the nurserymen is limited. Whether or not a disease potential is present, most nurseries routinely fumigate with M-C. Crop rotation or bare fallow, such as is used in Canada, has not been widely used in the United States. However, it has been quite effective in B.C. nurseries and deserves further testing in Northwest nurseries.

Other soil fumigants have been used in the past, but have not given consistent results. Recently a new method of application of an old pesticide metham-sodium (Vapam, Soil-Prep) has given good results. This material applied through the irrigation system effectively kills soil fungi, nematodes, insects, and weed seeds. It is somewhat less expensive than M-C, but requires careful application to obtain uniform coverage. The effect of this material on beneficial soil organisms has not been determined, but is under study.

Recent studies with contact nematicides have shown their effectiveness in nematode control. This provides nurserymen with another management option and enables them to be more flexible in the control program.

Newly developed fungicides are more specific in their activity and thus allow application against target organisms. The recent registration of Subdue allows for specific control of the water/mold fungi *Pythium* and *Phytophthora*. A specific control measure for soilborne *Fusarium* is still lacking and presently is the weak link in a soil pest management program. Once this

hurdle is overcome, it will allow greater flexibility in management and greatly reduce the cost of controlling these organisms.

#### FUTURE

Beneficial organisms in the soil are becoming more widely understood and utilized in practical ways. These organisms could be introduced into the soil or encouraged to develop to levels that would inhibit pathogenic organisms. There is still a ways to go before this is fully developed, but it has great potential for use in bareroot nurseries.

The value of these various types of soil management programs depends upon the degree of incorporation of these programs in the nursery. They will be of greatest value to nurseries utilizing the full program. This involves continually monitoring the crops and soil to establish threshold levels within the confines of the environment and management practices of the nursery. The eventual result should be reduced use of chemicals, or the use of chemicals directed against specific target organisms. This could be a very important factor since more and more soil applied chemicals are being found in the ground water and being removed from registration. As a result, in the near future we may be forced to look toward other management options.

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## MAXIMUM GERMINANTS/UNIT OF SEED AS A TOOL FOR CALCULATING BAREROOT

## AND CONTAINER SOWING CALCULATIONS

Raúl Moreno

**ABSTRACT:** The concept of Maximum Germinants per unit of seed (MG/unit) recognizes the fact that the germination percentage used in sowing calculations is directly related to a particular stratification treatment. By including the stratification requirements for a seed lot into the sowing calculations, MG/unit of seed helps to improve the correlation between laboratory and actual nursery germination.

## INTRODUCTION

Maximum Germinants/unit of seed is defined as the amount of live, normal germinants to be obtained under favorable germination conditions from a unit of stratified seed. Maximum Germinants per unit of seed can be expressed in pounds, kilograms, or total seed lot. For purposes of this paper, Maximum Germinants per pound (MG/lb) will be used.

In order to calculate the MG/lb of a given seed lot, we need to know the percent of germination and what stratification treatment was used to obtain this figure. Also needed is seed/lb, the percent of purity, and the percent of filled seeds in the seed lot. The percent of germination is actually a percentage of "apparent" germination which is the number of germinants as a proportion of all the seed in the sample (Edwards 1982). The type and duration of the stratification technique which the seed lot is subject to is directly related to the number of germinants obtained. The number of seeds per unit of seed (pounds, kilograms, or seed lot) is a function of seed size, moisture content (fresh weight basis), and the percent of filled seeds in the lot. Therefore, the lower the percent of filled seed, the greater the possibility of getting an inflated seed/unit figure. By including the percent of filled seed in the sowing formula, compensation for inflated seed/unit figures in lots with a high amount of hollow seed is accomplished. MG/unit of seed differs from Pure Live Seed (PLS) by the fact that it is tied directly to the type and duration of stratification technique that the particular seed lot was subject to, and also because it includes the percent of filled seed in the sowing calculation.

MG/lb = % of germination (under \_\_\_\_\_ stratification)  
X seed/lb X % pure seed X % of filled seed

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## LABORATORY TESTS

Laboratory seed germination test results are used to objectively evaluate a seed lot and to determine the sowing rates in the nursery. To obtain the necessary information to arrive at MG/unit of seed, a germination test is needed. Most laboratory germination tests are conducted with methods based on rules of the Association of Official Seed Analysts (AOSA) and/or the International Seed Testing Association (ISTA). Both AOSA and ISTA rules recommend that the seed testing of Douglas-fir and noble fir, for example, should be double test (with and without pre-chill), and that the pre-chill period should be 21 days (Anon. 1976, 1978). AOSA and ISTA recommendations for testing tree seed are good as a "referee" type of test. Referee testing is defined as comparative tests of the same lot using the same treatments at the same time (Edwards 1982). This type of seed testing is very useful for purposes of commercial trading and as an objective way to evaluate a seed lot. It does not, however, provide information on the ideal stratification treatment that the nursery grower needs in order to maximize the amount of pack-out seedlings obtained from a seed lot sown in the nursery.

According to the OSU Nursery Survey (Duryea and Landis 1984), in the Northwest, stratification periods vary from nursery to nursery. In the nurseries that responded to the survey, Douglas-fir and noble fir seed lots are subject to stratification periods that vary from 28 to 90 days. This variance between the nurseries' pre-sowing stratification treatments (28 to 90 days) and the 21-day chill treatment in the seed laboratory may explain why, in some cases, the germination reported by the seed laboratory correlates very poorly with the actual nursery seedling emergence. To complicate matters a little more, all nurseries responding to the OSU survey use some type of "naked stratification." Naked stratification is when the seed is soaked in a plastic bag or other suitable container for 24 to 48 hours, drained of excess water, and placed at a low temperature for a predetermined period of time. Not all of the seed laboratories give the seed samples a water soak stratification when doing the chill part of the germination test. Some seed laboratories place the dry seed on top of a moist medium and then proceed to place the sample in a cooler at low temperatures. Therefore, not only the duration but, in some cases, not even the type of stratification is being duplicated between the nursery and the seed laboratory.



## SEED LOT RESPONSE

Seed lots are unique in that they come from different geographic areas, elevations, slope exposures, crop years, and maturity levels at the time of harvesting. Also, the processing techniques and storage conditions which they have been subject to might have been different from seed lot to seed lot. Therefore, seed lots from a given tree species will not always respond similarly to a particular stratification treatment prior to sowing. If the objective is to maximize the germination capacity of a seed lot and influence its germinative energy peak so this germinative energy will occur soon after sowing, we need to properly identify the best stratification technique for each seed lot. That can be done in the seed laboratory at the time of doing the germination test by conducting more than one type of pre-chill treatment per seed lot tested. In doing more than one pre-chill treatment, it is evident that some of these variations will show a significant increase in total germination over the standard 21-day chill referee test. It is this kind of "custom seed testing" that the grower needs in order to arrive at more accurate sowing calculations. Also, with this kind of stratification information, the nursery person can decide which stratification treatment is the most advantageous based on the nursery's own particular growing objectives. For example, the grower might be concerned with a very rapid germination (even if it comes at the expense of the total germination capacity of the seed lot) since rapid germination patterns none a strong influence on the final pack-out seedling yield and quality. In another situation, the nursery might not have enough seed from a particular valuable seed lot and the grower would be interested in maximizing the total germination capacity of the seed lot in order to get as many seedlings from the seed lot as possible.

For bareroot nurseries, the use of MG/unit of seed can simplify the sowing calculations. If the information needed is how many pack-out seedlings can be obtained from a given unit of seed, then MG/unit of seed (being pounds, kilograms, or seed lot) needs to be multiplied by the specific survival factors of the nursery for that particular tree species and seedling type. A problem may arise, as suggested by Thompson (1984), by the fact that nursery survival factors used in the sowing formula are, "at best, an average of many years of experience and, at worst, a conservative educated guess." In the best of cases, when survival factors have been recorded over a period of years, in an average year the actual pack-out seedlings should be very close to the expected seedling yield. Now, in the situation where there is not much information available and the grower is forced to make a guess, the concept of MG/unit of seed can play a helpful role in actually identifying more closely the actual survival factors of the nursery. If the grower knows how many germinants he/she can potentially get from the seed lots sown under ideal conditions, at the end of the growing period the grower can divide the pack-out number of seedlings by the MG/seed lot and the result will be a survival factor for that particular seed lot, that particular year. For example, if the

MG/seed lot was 160,000 but the final pack-out figure was only 80,000 seedlings: 80,000 divided by 160,000 equals .5 or 50 percent survival.

## MG/UNIT EXAMPLES

The following is an example of how the concept of MG/unit of seed was used in a bareroot nursery. The seed lot was collected, tested, and stratified by Syverson Seed, Inc., Ridgefield, Washington, and sown at the J. Hofert Forest Nursery, Olympia, Washington, in May of 1984.

Seed lot used.....noble fir 440-35-82  
expected pack-out...47,300 (2+0 seedlings)  
seed per pound.....12,250  
seed purity.....98.8 percent  
filled seeds.....80 percent

In order to properly identify the most favorable stratification treatment, a custom germination test was done. In addition to the standard no-chill germination test, four more tests were done, each with a different treatment (table 1).

Table 1.-- Variable chill treatment used in a custom germination test in order to determine the most advantageous stratification treatment for a noble fir seed lot

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Test A. - no chill treatment  
Test B. - 30 days moist chill treatment  
Test C. - 60 days moist chill treatment  
Test D. - 30 days moist, surface dried and then  
          30 days dry chill treatment (30/30)  
Test E. - 50 days moist, surface dried and then  
          40 days dry chill treatment (50/40)

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The results from this test, expressed in total percentage of apparent germination (fig. 1), showed that the stratification treatment applied to test "D" resulted in a significant increase in total germination over the other treatments and that its germinative energy peak was in the first 14 days of the test.

With the available germination data, the sowing rates were calculated:

- .62 germ. (30/30 strat) X 12,250 seed/lb  
X .988 seed purity X .80 filled seed =  
6,003 MG/lb
- 6,003 MG/lb X .75 (mortality 1st year) X .80  
(mortality 2nd year) X .90 (cull factor) =  
3,241 pack-out seedlings/lb of seed
- 47,300 expected yield ÷ 3,241 seedlings/lb =  
14.6 lb of seed needed

On May 15, 1984, the seed lot was sown using a Wind River seed drill over 528 linear bed feet. The density per square foot was:

- 47,300 seedlings ÷ 528 bed feet = 89.6/bed foot
- 89.6 seedlings/bed foot ÷ 4 sq ft/bed ft =  
22.4 pack-out seedlings/square foot

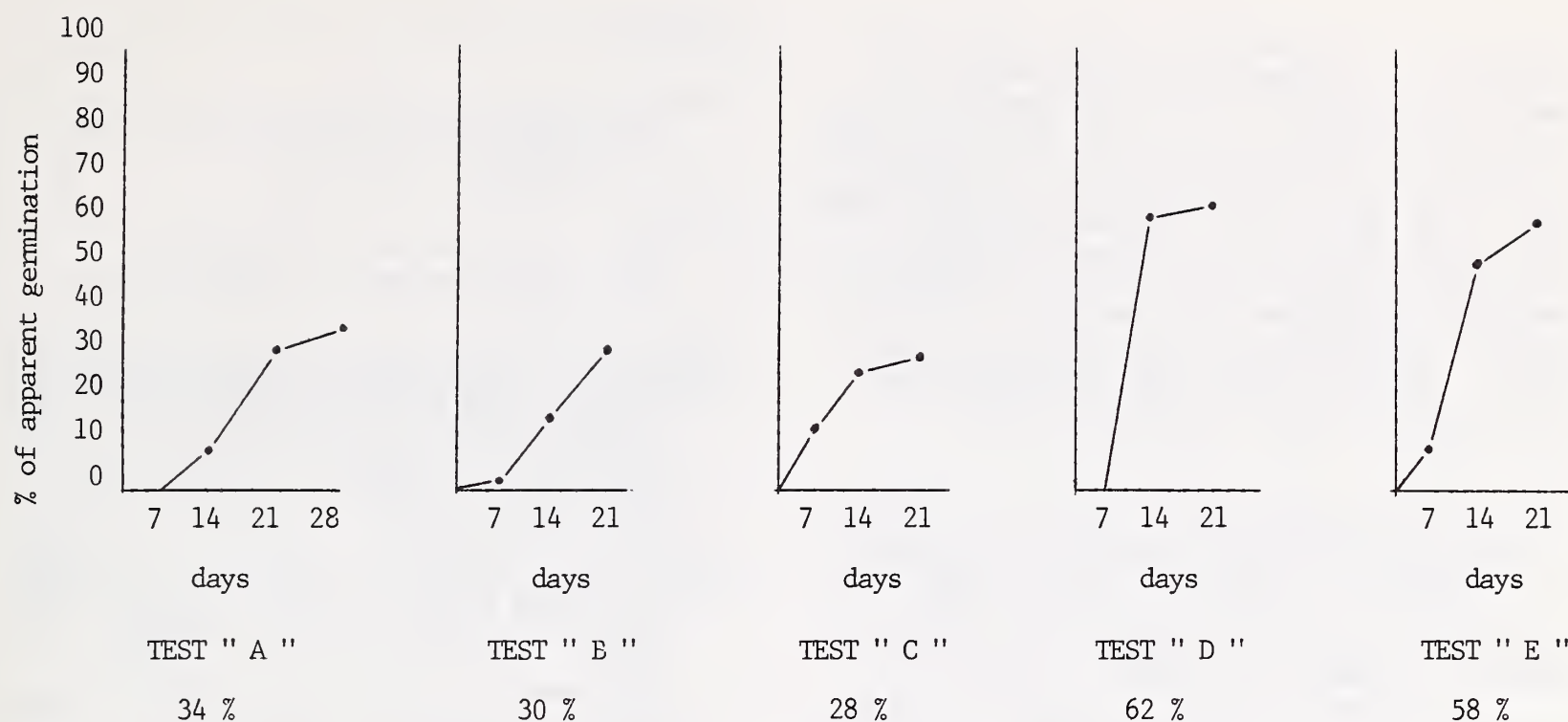


Figure 1.-- Percent of germination obtained under different chill treatments for a noble fir 440-35-82 seed lot.

To verify the actual survival factors in the nursery, a test plot of 2 linear bed feet was set up in order to monitor field germination.

- 6003 MG/lb X 14.6 lb seed = 87,643 MG/seed lot
- $87,643 \div 528 \text{ bed ft.} = 166 \text{ MG/bed ft} \times 2 \text{ bed/ft} = 332 \text{ MG/2 bed feet test plot}$

Seedling emergence was first recorded 15 days after sowing and from then on every 7 days until germination was completed (table 2). In the first 37 days after sowing, there was very little mortality (two seedlings) and the correlation between the actual test plot seedling emergence (342 seedlings) and the expected maximum germinants in the test plot (332 germinants) was very close. Also, the germinative energy peak shown in test "D" was very similar to the one experienced in the test plot (fig. 2).

In a container nursery, the concept of MG/seed lot can be very useful in determining whether or not there are enough potential germinants for the number of cavities that need to be sown. For example, the following seed lot was sown at the Syverson Seed container facilities in Ridgefield, Washington, in March of 1984.

seed lot.....noble fir 452-35-78  
total seed lot...146 lb  
total cavities...214,560 styro 2A cavities

- MG/seed lot = 146 lb X .18 germination (under 30/30 stratification) X 13,594 seed/lb X .97 seed purity X .74 filled seed = 256,376 MG/seed lot
- $256,376 \text{ MG} \div 214,560 \text{ cavities} = 1.19 \text{ MG/cavity}$

Table 2.-- Field germination of the NF 440-35-82 seed lot in the test plot at the J. Hofert Forest Nursery

15 days after sowing -	73 seedlings
22 days after sowing -	224 seedlings
29 days after sowing -	306 seedlings
37 days after sowing -	342 seedlings (-2) <sup>1</sup>
44 days after sowing -	333 seedlings (-9) <sup>1</sup>
51 days after sowing -	332 seedlings (-1) <sup>1</sup>

<sup>1</sup>Dead seedlings since last count.

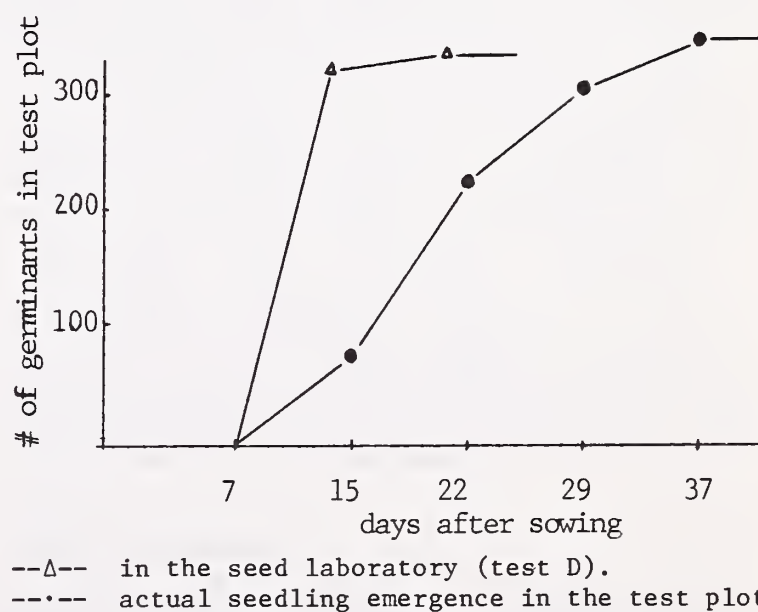


Figure 2.-- Comparison of the germinative energy peak between the laboratory germination test "D" and the seedling emergence in the test plot.



If the ratio of MG/cavity is greater than 1.00, the seed lot has enough potential germinants to qualify for "germinant sowing". Germinant sowing is the procedure in which the seed is germinated prior to sowing and then each germinant is transplanted by hand into each container cavity. It is possible that a ratio of less than 2.50 MG/cavity would require substantial filling of empty cavities with germinated seedlings obtained from thinning the cavities which have multiple seedlings. A ratio of more than 2.50 MG/cavity might ensure that the majority of the cavities would have seedlings in them. Further studies are required in order to determine the proper ratio of MG/cavity for a container sowing formula.

And finally, one more area in which the concept of MG/unit of seed can be very valuable is as a common terminology for the forester, the seed company, the seed laboratory, and the nursery grower when referring to a particular seed lot in terms of its potential to produce seedlings.

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"GROW & PLANT"--ANOTHER WAY TO DO THE JOB //

Frank A. Rothe

ABSTRACT: Two-year survival rates for ponderosa pine seedlings grown and planted by a contractor were higher than rates for seedlings grown and planted by the Government at nearby sites in 4 contract years. A better partnership arrangement between contractors and management agencies, featuring performance and bonus payments, should result in increased seedling survival. A Government-private industry task force should be formed to discuss the proposal.

#### INTRODUCTION

For 6 years Colo-Hydro Inc. contracted with the Bureau of Indian Affairs to "Grow & Plant" ponderosa pine seedlings to reforest a burned area near Ruidoso, NM.

Between 300,000 and 400,000 containerized seedlings were grown and planted each year. The Government supplied the seed, the seedling specifications, and the planting specifications. The contractor grew the seedlings and delivered them to the site and planted them in the forest.

The payment schedule was as follows: 30 percent when crop was planted in greenhouse; 30 percent when trees were delivered; 40 percent when trees were planted in ground.

The Government inspected the seedlings prior to each progress payment and inspected the planting on a daily basis. The total payment for the contract was based solely upon the number of trees satisfactorily spaced and planted in the forest.

At the same time the Government produced seedlings in its own facility and managed its own planting contracts on adjacent tracts. The 2-year survival rates for the 1978-81 plantings were consistently higher than the plantings made by the Government. Survival data for the 1982 and 1983 plantings are not yet available.

This is not intended to indicate that private individuals are better managers than the Government representatives. Instead, it reflects the fact that contractors, and specifically small

businesses, have a great deal more flexibility than do Government contracting officers.

#### PRIVATE ADVANTAGES

The problem is to motivate people to do good work. Here the private manager has much more freedom than his Government counterpart.

First, he does not have to take the low bidder. He can select the bidder who'll make him the best profit and who'll minimize the prospects of default. Second, he can give longer term work assurance. If a contractor feels that a superior job done now will help to get him the job next time, he will be more motivated to do a good job now.

Third, he has more freedom to hire and to fire personnel. Under the "Plant & Grow" contract the seedlings were taken to the forest in their trays. These trays included about 10 percent empties and culls. It became obvious that some of the planters were planting the culls. A retired man was engaged on a part time basis to account for the seedlings taken out and to count the culls coming back. By the second day he was able to tell who were planting culls. The cost of this extra help was very minimal, and there were no delays or complications or special forms to fill out to hire him and lay him off.

Fourth, the private manager has more flexibility to respond to situations that arise on the job. In one instance, too many seedlings were being planted unsatisfactorily in spite of the fact that the planting crews had to pay for the seedlings that were poorly planted. The manager offered a \$100 daily cash bonus to the crew that had the lowest percentage of unsatisfactorily planted trees. This was passed out in cash every night. Within a few days the individual planters were watching to see who in their crew was doing the bad planting. With the peer pressure and the increased awareness the problem went away. The extra flexibility available to the private manager is an asset that can be used to the credit of the Government.

#### A BETTER COMBINATION

Might it be possible to develop a better combination of Government and industry participation which will improve reforestation success?

How can we further tap the flexibility and the advantages available to the private sector to the best interest of the Government?

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Paper presented at combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Coeur d'Alene, ID, August 14-16, 1984.

Frank A. Rothe is President, Colo-Hydro, Inc., Longmont, CO.



The ultimate goal is to have trees surviving in the forest.

Any concept designed to achieve a more effective Government and industry partnership to achieve this goal must consider many things.

1. What is the effect on the contracting officer who must protect the Government interest and work within certain restraints?

2. What is the effect on Timber Management Officers who want to assure quality work on a timely basis in order to take advantage of site preparation and moisture conditions?

3. What is the effect on the contractor? He must not be asked to take risks over which he has no control (weather, soils, seed quality, site preparation, etc.).

4. Any such concept must address the problem of progress payments. The ultimate measure of performance is the number of trees surviving in the forest. The extent of survival cannot be evaluated until 1 to 2 years after the planting. Therefore, progress payments must be made to the contractor without further increasing the risk to the Government.

#### REWARDS MOTIVATE

It seems to be clear that in our society a reward for above normal performance is a much greater motivator than a penalty for below normal performance.

One possible scenario for improving motivation might be as follows. Let us assume for the purpose of conveying an idea that:

Price of seedlings	=20¢
Price of planting	=30¢
Total cost of operations	=50¢

Now let us assume that the normal survival	=66 pct.
Then the cost per live tree	=75¢

Now let us suppose that the final payment on the contract is 75¢ per tree surviving after 1 or 2 years. To cover the contractor's needs, progress payments are made for seedlings when they are finished, and for the planting when it is completed.

To protect the Government, these progress payments could be based upon the numbers of seedlings meeting the specifications and the number planted and spaced according to specification. Thus the risk to the Government would not be any greater than under the current practices.

The contractor on the other hand would receive payment for growing and for planting as in the past. In addition he would receive a bonus for survival in excess of the normal. If he can increase survival by 10 percent he will increase his income by 10 percent and increase his profit by significantly more than 10 percent. Most small business entrepreneurs would respond to

this with a special and imaginative effort to achieve better survival.

At the same time the Government will still be paying 75¢ per tree.

#### TASK FORCE NEEDED

Now it is recognized that the above example leaves some questions unanswered. However, there is a clear view of areas to explore. A fruitful discussion of these areas could best be achieved by a small group made up of members of the Government and members of the private sector.

Toward this end it is proposed that a task force be formed to explore the possibilities for a new approach designed to direct motivation toward ultimate seedling survival.

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## FIELD PRODUCTION OF ROOTED POPLAR CUTTINGS FOR PRAIRIE PLANTINGS

W. R. (Bill) Schroeder

**ABSTRACT:** The Prairie Farm Rehabilitation (PFRA) Tree Nursery at Indian Head, Saskatchewan, produces 300,000 rooted poplar cuttings annually for farmstead shelterbelt plantings in the Canadian prairie provinces. Hardwood cuttings collected from stooling beds are planted during the last two weeks in May with a tractor-drawn mechanical planter capable of planting 80,000 cuttings per day. Four months after planting, rooted cuttings are mechanically harvested for shipping to prairie farmers the following spring.

## INTRODUCTION

The first homesteaders to arrive in Western Canada soon appreciated the value of trees and shrubs as a means of protecting their homes and livestock from the wind. Early attempts at establishing trees imported from the United States and Eastern Canada met with little success, due to the dry climate and harsh prairie winters. As a result the Canadian government established a nursery in 1902 at Indian Head, Saskatchewan, to provide hardy tree and shrub material for prairie farmers. Orders for seedlings increased from a few thousand in 1904 to more than two million in 1910. To date over 450 million seedlings have been distributed to prairie farmers by the PFRA Tree Nursery.

Shelterbelts are as important to prairie farmers today as they were at the time of settlement. In addition to farmstead belts, shelterbelts are now used as roadside plantings to reduce road maintenance costs by preventing blockage by snow. During the past 40 years there have been periods during which there was considerable interest in the use of field shelterbelt plantings. This has been especially true in those areas where soil drifting is of concern. In the dry 1930's, over 1,000 miles (1 600 km) of field shelterbelts were established. Interest in field shelterbelts continues with over 400 miles (640 km) planted annually. More recent tree planting developments include watershed protection plantings and specialized plantings for wildlife and land reclamation sites.

Poplars have been used for shelterbelt and amenity purposes on the prairies since the turn of the century. Early settlers used the native aspens in

farmstead shelterbelts because the species grew readily under various soil and climatic conditions and provided reasonably quick protection from winds and drifting snow. However, the shortcomings of the native poplar species became evident and more suitable hybrid clones were developed or introduced. The major species and clones planted over the years were plains cottonwood, Russian poplar, Northwest poplar, and Walker poplar. Northwest (P. deltoides x P. balsamifera) and Walker (P. deltoides cv. 'Walker') poplars are the clones that are presently distributed by the tree nursery. Northwest is a hardy male clone, characterized by moderately fast growth and a spreading form, whereas Walker poplar is a very fast growing, upright, female clone that is moderately resistant to most common insects and diseases. Since poplar was first produced in 1909, 15 million unrooted cuttings and 4 million rooted cuttings have been distributed by the tree nursery to prairie farmers. Demand for poplar remains high with approximately 300,000 rooted cuttings distributed annually with the majority planted in farmstead shelterbelts where rapid growth is desired.

## EQUIPMENT DEVELOPMENT

From 1909 until 1966 an average of 300,000 unrooted hardwood cuttings of poplar were produced and distributed annually for farm shelterbelt plantings. During this period, some cuttings were rooted prior to distribution, either by covering them with soil manually using shovels or by placing cuttings in ploughed furrows, then covering and packing. These labor-intensive methods restricted mass production of rooted cuttings so that it was necessary to distribute unrooted hardwood cuttings for shelterbelt plantings. However, the plantings often failed during dry years. As a result, the development of a mechanized nursery planter that would facilitate large-scale production of rooted cuttings was essential.

The first prototype mechanical planter, developed in 1963, utilized a chisel that made a 10-inch (25-cm) planting trench. Although this planter increased the speed of planting, the cuttings were often damaged. In 1964 a planting mechanism made up of two pairs of hydraulically driven-rubber-faced rollers was developed by tree nursery staff (fig. 1). The rollers grasped cuttings that were fed singly into a hopper and inserted them into the chisel trench. Further modification to this basic unit included changes to the planting mechanism that facilitated replacement of worn rollers and packing wheels that would push 6-inch (15-cm) cuttings to ground level. Two four-row planters with these modifications were capable of planting 750,000 hardwood cuttings in less than four days (fig. 2).

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Paper presented at combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Coeur d'Alene, ID, August 14-16, 1984.

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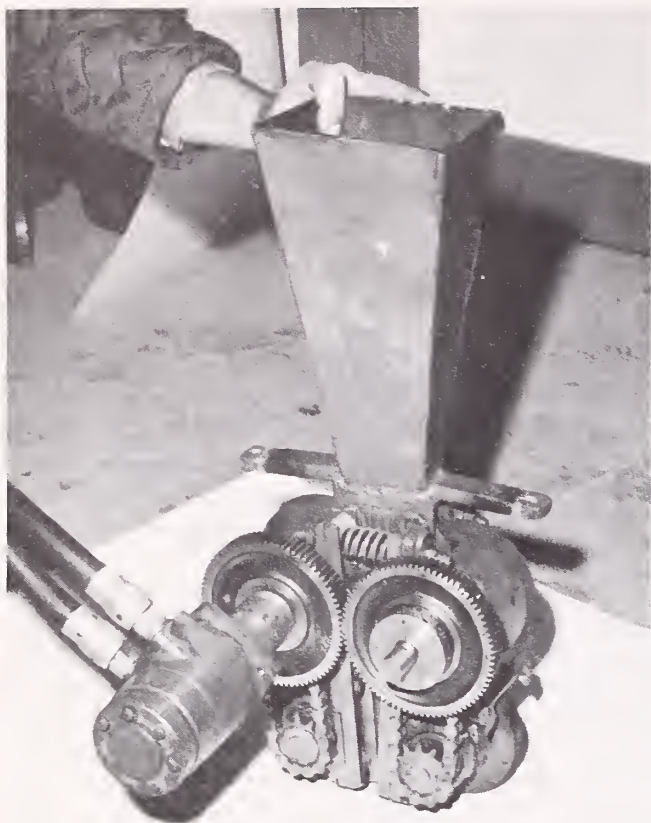


Figure 1.--Hydraulic four-roller cutting planting mechanism.



Figure 2.--Four-row cutting planter in operation.

#### POPLAR PRODUCTION

A major activity in poplar production is the establishment and maintenance of poplar cutting beds. Successful production of cuttings is a function of the intensity of nursery cutting bed management. As a result, cultural practices such as weed control, irrigation, and pest control are essential for maximum cutting production. Cutting beds have a productive life of approximately 9 years after which they should be removed and new beds established at regular intervals. In order to produce the number of cuttings required each

year, approximately 15 acres (6 ha) of beds are maintained. The harvesting of whips for cutting production is done in the late fall and involves tying branches in bundles and cutting the stems with a sickle mower. All side branches are pruned flush with the stem which is then cut in 6-inch (15-cm) lengths with a pneumatically driven knife and placed on a conveyor belt. As the cuttings pass along the conveyor belt, they are graded to a uniform size and then dipped in a benlate fungicide prior to overwinter storage at 28°F (-2°C) in polyethylene-lined bins.

The hardwood cuttings are generally planted during the last 2 weeks of May. The mechanization of poplar production dictates that the soil be loose and friable. Therefore the fields are rotovated to a depth of 8 inches (20 cm) prior to planting. Cuttings are inserted into the soil by feeding two sets of rubber-faced rollers driven at high speed by hydraulic motors. Operators drop cuttings individually into a small hopper as fast as possible so that plant spacing ranges from 1 to 2 inches (2 to 5 cm). The inserted cuttings are pushed to ground level with a rubber slotted metal packing wheel attached to the rear of the planter. Immediately following planting the field is leveled and packed and then sprayed with linuron at a rate of 2.21 lb/ac (2.5 kg/ha) which provides weed control during the entire growing season. Irrigation is applied immediately after spraying and throughout the growing season as required. Crops are closely monitored and immediate action is taken if insect or disease problems arise.

After 4 months, the rooted cuttings are ready for harvest (fig. 3). Prior to lifting, the young plants are topped to a uniform height of 14 inches (35.5 cm) which facilitates mechanical harvesting and handling as well as providing for a good top root ratio. After leaf drop (natural or induced with the chemical defoliant endothall) the rooted cuttings are lifted, placed in wooden pallet boxes, and transported to the packing shed for sorting. The rooted cuttings are stored overwinter in polyethylene lined bins at 28°F (-2°C) heeled-in outdoors. The following spring the young plants are bundled and shipped to farmers for planting in farmstead shelterbelts.



Figure 3.--An unrooted cutting (A) and a 4-month old rooted cutting (B).



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## TRANSPLANT COMPARISONS AT THE WEBSTER NURSERY

PLUG-1s AND BARERoot 2-1s //

James M. Sedore and William Fangen

**ABSTRACT:** August and March transplanted plug-1s are compared with 2-0 and 2-1s. Plug-1s were generally larger than 2-1s. Although some seedlings lost needles in a severely cold winter the seedlings recovered the following season.

## INTRODUCTION

We have been growing bareroot transplants for many years at the Webster Nursery. In 1981 we began raising container seedlings for transplanting. After three years of experience we have made some comparisons.

## REASONS FOR PRODUCING TRANSPLANT STOCK

Transplant stock types are planted where browsing and vegetative competition are problems for smaller seedlings. Plug-1 stock is significantly larger than plug stock. Larger seedlings with a balanced shoot/root ratio, caliper, and root symmetry have a better chance at reaching release size in browse and competition sites than smaller stock.

The second reason for transplanting container stock is the unique characteristics of Douglas-fir plug-1s. Bareroot 2-0 Douglas-fir often grow too tall for easy transplanting. Even when transplanting only the smaller seedlings the trees are spaced farther apart than other transplanted species, 18 stems/bedfoot. This requires additional bed space which adds to the cost. Container 1-0 Douglas-fir are planted at 21 stems/bedfoot. All the seedlings that meet a minimum specification are transplanted. The root mass that develops from the plug has a mop-like appearance (fig. 1). This contrasts with the more spreading root-mass of the 2-1. Some tree planters prefer the plug-1 root system for its ease of planting.

The third reason for plug-1s is the ability to produce a transplant seedling in 2 years rather than 3 years.

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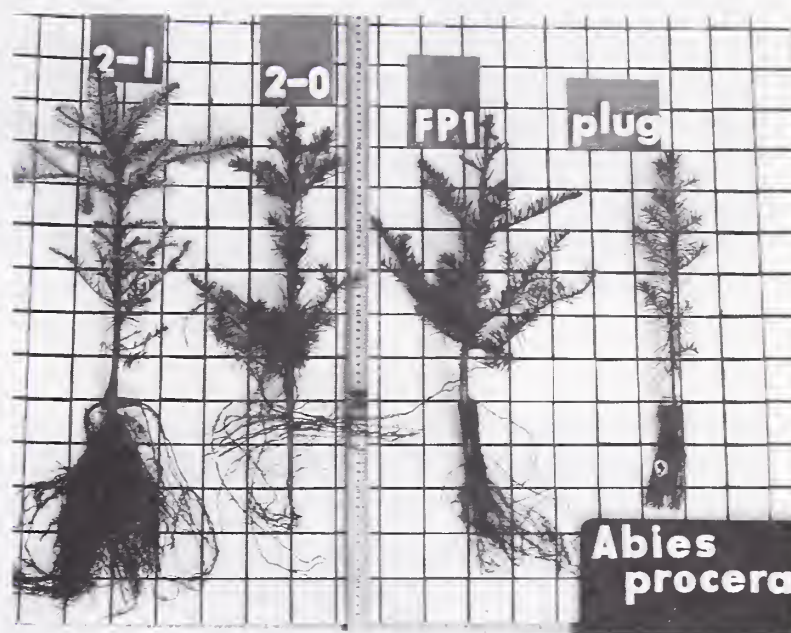


Figure 1.--Comparison of root configuration between bareroot and container transplants.

Table 1.--Average measurements of different stock types grown at the Webster Nursery, October, 1983

Species	Stock type	Height cm (in)	Caliper mm	Shoot/root (fresh wts)
Douglas-fir ( <i>Pseudotsuga menziesii</i> )	2-0	45 (18)	5	2.1
	2-1	58 (23)	7	1.7
	AugP-1	65 (26)	11	2.2
	MarP-1*	58 (23)	8	2.0
Sitka spruce ( <i>Picea sitchensis</i> )	2-0	34 (13)	6	2.2
	2-1	45 (18)	8	
	AugP-1	53 (21)	8	1.7
Noble fir ( <i>Abies procera</i> )	2-0	34 (13)	8	4.7
	2-1	36 (14)	9	
	AugP-1	35 (14)	8	4.2
Western hemlock ( <i>Tsuga heterophylla</i> )	AugP-1	62 (24)	8	2.1
	MarP-1	42 (17)	6	3.0
Western redcedar ( <i>Thuja plicata</i> )	AugP-1	71 (28)	9	5.1
	MarP-1	64 (25)	6	7.6
Silver fir ( <i>Abies amabilis</i> )	AugP-1	25 (10)	7	1.7
	MarP-1	26 (10)	7	1.4

\*Measurements from October, 1982

## MORPHOLOGICAL COMPARISONS

August Plug-1 Douglas-fir (*Pseudotsuga menziesii*), Sitka spruce (*Picea sitchensis*), and noble fir (*Abies procera*) were all equal to or larger than 2-1 transplants (table 1) (figs. 2-7).





Figure 2.--Western redcedar transplant comparisons.

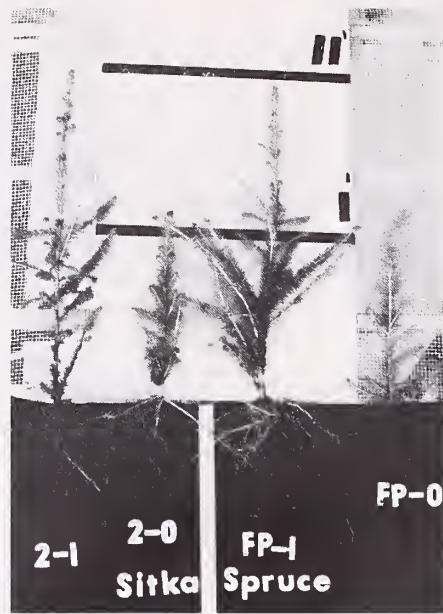


Figure 3.--Sitka spruce transplant comparisons.



Figure 4.--Pacific silver fir transplant comparisons.



Figure 5.--Western hemlock transplant comparisons.

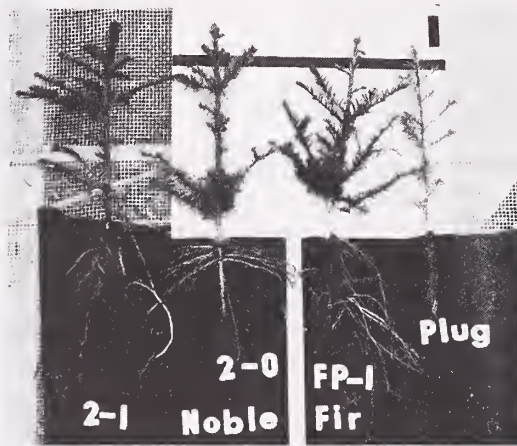


Figure 6.--Noble fir transplant comparisons.



Figure 7.--Douglas-fir transplant comparisons.

August transplants of western hemlock and western redcedar were larger in height and caliper than March transplants. We do not raise 2-1 hemlock or silver fir so no comparisons could be made.

#### NEEDLE BURN ON PLUG-1s

The annual cold spells at the Webster Nursery are usually brief and no lower than 10°F (-12°C). However, in 1983-84 the temperature reached -7°F (-21°C) and stayed below freezing for 7 days. One month later it again dropped below 20°F (-7°C) for 7 days. Needles of many of the plug-1s were injured and fell off in March. We did not know if the cold had killed the roots, cambium, or the buds, so we photographed the seedlings monthly (figs. 8-17). As the photos show the seedlings recovered well. This ability of transplants to lose their needles from winter cold burn and yet recover should be noted when making plantation surveys in the spring.





Figure 8.--Western redcedar,  
January 20, 1984.

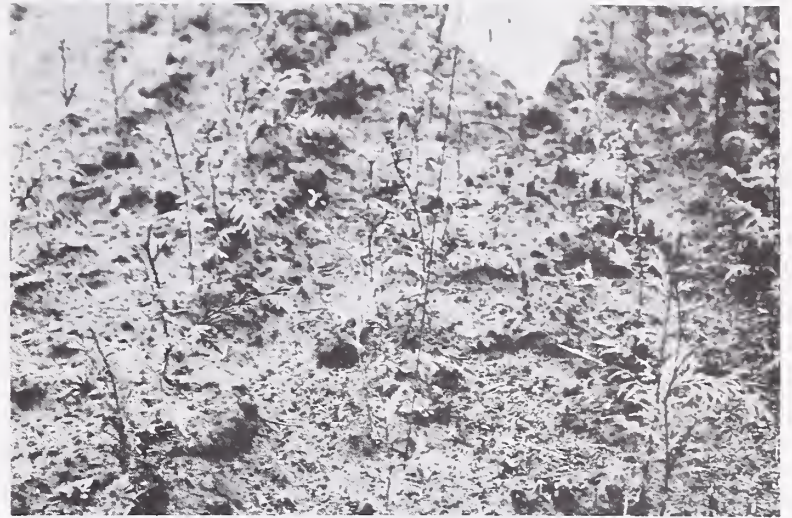


Figure 9.--Western redcedar, March 1, 1984.



Figure 10.--Western redcedar, April 2, 1984.



Figure 11.--Western redcedar, May 21, 1984.



Figure 12.--Western redcedar,  
July 3, 1984.





Figure 13.--Western hemlock, January 20, 1984.



Figure 14.--Western hemlock, March 1, 1984.



Figure 15.--Western hemlock, April 2, 1984.



Figure 16.--Western hemlock, May 21, 1984.



Figure 17.--Western hemlock,  
July 3, 1984.



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## GROWING SEEDLINGS IN PALLET-SIZED CONTAINERS //

William A. Sery

**ABSTRACT:** A palletized planting frame system used since 1970 to produce progeny for rust-resistance screening tests could be adapted to produce seedlings for other purposes. A polystyrene or polyethylene pallet is used as a base; sidewalls are plywood. The system allows use of an artificial soil mix, eliminating the need for fumigation, and makes it easy to move seedlings in and out of inoculation chambers.

## INTRODUCTION

Western white pine (*Pinus monticola*), sugar pine (*Pinus lambertiana*), and lodgepole pine (*Pinus contorta*) seedlings are grown in pallet-sized containers for the rust screening program at Dorena Tree Improvement Center. Dorena has been using this size container, which is called a planting frame, since about 1970.

Native soils at Dorena consist of heavy clays, which makes growing trees very difficult and producing uniform seedlings impossible. The palletized planting frame system was devised to provide a good growing medium for conducting progeny tests for screening for resistance to blister rust and western gall rust. Having the planting frames on pallets also facilitates moving the seedlings in and out of the inoculation chamber.

This system, which has worked quite well at Dorena, is being presented with the idea that others may find it of value in specialized situations. Other nurseries that have soil problems may find growing seedlings in planting frames to be superior to growing them in native soil. Proper nutrient levels are easier to maintain in a uniform soil mix, which permits production of superior seedlings.

## PLANTING FRAME CONSTRUCTION

The process begins with construction of the planting frames. A 40-inch by 48-inch (102-cm by 122-cm) pallet is used as a base. The pallet needs to be rigid and strong enough to hold a 1,500-pound (682-kg) load. It should also be flexible enough to accept some degree of deformation without breaking. Since pallets at Dorena are recycled every

7 years, they must have sufficient elasticity to return to their original shape after sitting on slightly irregular ground for several years under load. Polystyrene has proven to have all these properties. Some of the better grade polyethylene pallets also meet acceptable standards and are cheaper.

Good-grade polystyrene and polyethylene have been used successfully at Dorena for the past 8 years. Each pallet has 216 3/8-inch (.95-cm) diameter holes, which allows water to drain from the pallet. This is very important, especially for moisture sensitive species like sugar pine.

Of a wide variety of plastic pallets available on the market, only a few are acceptable for planting frames. Many commercial pallets do not have adequate strength and are designed to be disposable for one-way shipments. Some do not have any holes for drainage and others have such large holes that soil mix would fall right through. If pallets are not to be reused, they can be constructed of wood at a cost of about \$14.00 per pallet exclusive of labor.

The sidewalls of the planting frames are made of 3/4-inch (1.9-cm) plywood, 1 foot (30.5-cm) high. The plywood is cut to the proper dimension and nailed together. Two bands of 3/4-inch (1.9-cm) wide steel strapping material are wrapped around the outside of the frame and drawn tight to keep the frame from falling apart when it is in use or being transported. The plywood upper frame is then attached to the pallet using 2 by 4's and nails.

About 2 inches (5-cm) of drain rock is placed in the bottom of the frames. This provides drainage and also acts as a barrier between artificial soil media in the frames and the native soil beneath the frames.

## SOIL MEDIA

The frames are placed in position and filled with artificial soil media. Dorena is currently using a commercially-prepared mixture of 50 percent peat moss and 50 percent vermiculite with added nutrients. This mix comes in 4 cubic feet (.11m<sup>3</sup>) bags which are light and easy to handle. Each frame holds 14 cubic feet (.40m<sup>3</sup>) of mix or approximately 3 1/2 bags.

Dorena used 50-50 peat-sand mix for several years that was mixed in a concrete truck. The peat-vermiculite produces superior seedling growth over peat-sand with greater uniformity. Peat-sand was cheaper to buy, but the overall cost was greater because of material handling costs. The need for

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fumigation was eliminated with the new mix so all the labor involved in setting up a fumigation tent was eliminated. Elimination of fumigation also allows for sowing the seed about a month earlier, thus avoiding many fungi problems in the nursery. Peat-vermiculite mix is also considerably lighter than peat-sand mix which means lighter loads for forklifts and trailers.

#### USE AND PROBLEMS

Western white pine, sugar pine and lodgepole pine are sown in the frames in March. The familial origin of each row of seedlings is identified on the side of the box. Seedlings are sown at Dorena to screen for white pine blister rust and western gall rust. At the end of the second year, the frames are moved into an inoculation chamber where they are inoculated with the rust fungus. They are then placed back in their original positions where rust development is monitored for another 5 years. This means that seedlings are grown in the planting frames for a total of 7 years.

Rodent damage has been a problem. Field mice and gray diggers are the major culprits, but an occasional crow attack has been experienced. Frame tops, which consist of another frame covered with hardware cloth, are placed over the planting frames to provide a physical barrier. An active baiting program is conducted to reduce rodent populations.

Irrigation is accomplished by a shrub head system that projects a fine mist over the frames. Shrub heads are arranged in a head-to-head configuration, which provides even coverage. Solenoid valves are connected to an electronic control device that can be programmed to turn each station on and off at the desired time. Each station can be programmed to come on for a few seconds at a time to provide cooling without significantly increasing the moisture content of the soil. Moisture levels are monitored using gypsum blocks and visual observation.

Fertilizer is injected into the irrigation system in liquid form. Peters fertilizer is used on 1-year-old seedlings because of its demonstrated success at standard container nurseries. Other brands may work as well. An 8-8-8 fertilizer is commercially prepared for use on the older seedlings. Trace elements are also added through the irrigation system. Routine soil sampling is performed, and some samples are also sent off for foliar analysis.

The purpose of growing seedlings in this manner at Dorena is to progeny test phenotypically selected trees for resistance to rust. This system is not used to produce seedlings for reforestation, although it could be adapted to do so. Costs of doing this would be high, but it may be cheaper than building up poor-quality native soils.

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## FOUR INSECT PESTS OF CONIFER NURSERIES

IN BRITISH COLUMBIA

Gwen Shrimpton

ABSTRACT: Four pests of conifer nurseries in British Columbia, the strawberry root weevil, tarnished plant bug, European marsh crane fly, and conifer root aphid, are described. Their general pest status, occurrence in the nurseries, life history, damage, and control are briefly discussed.

## INTRODUCTION

Increased demand for seedlings has made nursery managers more aware of pest losses. Insect damage can affect both the quality and quantity of seedlings and may indirectly affect reforestation plans. Use of insecticides can also lead to environmental contamination. This paper outlines two insect management programs based on the biology of the insect, that have been developed in British Columbia (B.C.) nurseries and provides information on two recently identified insect pests.

## STRAWBERRY ROOT WEEVIL

The strawberry root weevil, Otiorhynchus ovatus, is primarily a pest of strawberries and related plants and occasionally damages conifer seedlings in the Pacific Northwest. Ovatus ranges across North America in a broad band, covering all the provinces of Canada and the northern half of the United States. It is particularly abundant in the humid climate of the coastal regions (Warner and Negley 1976). In B.C. conifer nurseries it has been a notable pest of bare-root conifers at Surrey Nursery.

There is one generation a year with both adults and larvae overwintering. Adults become active in mid-April and begin egg-laying in May. Larvae that overwinter emerge as adults during June, and feed for about one month before becoming sexually mature.

Newly emerged adults are tan. When mature, they are dark-brown to black, about 1/4-inch (6.0 mm) long, and egg-shaped in outline. Adults are flightless and all are females. Usually the adult insects rest during the day in protected places. At night, temperature permitting, they

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feed on plant foliage, including conifer seedlings, and often chew the needles off close to the stem.

The larvae are up to 3/8 inches (1.0 cm) long, slightly curved, creamy white with brown heads, and legless. They inhabit the top 10.0 inches (25 cm) of the soil around host plant roots. In heavy infestations there can be as many as 300 larvae per square foot (3000 per m<sup>2</sup>).

In conifer nurseries the larvae eat the fibrous roots of the seedlings, stripping most laterals. In heavy infestations, they may even girdle the root collar. In bare-root stock, damage has occurred predominantly along the edges of 2+0 panels. It is usually in patches, because weevils are somewhat gregarious. There has been no notable damage in 1+0 stock to date, and the insect does not appear to be host-specific. One indication of weevil damage is the ease with which seedlings can be pulled from the ground. Strawberry root weevil damage is often not detected until the seedlings are lifted, although seedlings may become chlorotic during the fall.

Strawberry root weevil populations at Surrey Nursery are monitored by using board traps to determine the length of the adult emergence period, the distribution of the weevils throughout the nursery, and the effectiveness of the control programs. However, these traps do not give a reliable estimate of the numbers present or provide control. Traps are one-foot (30.0-cm) lengths of "two-by-four" placed flat on the soil surface, flagged with tape, and numbered. These simple traps work because adult weevils feed on foliage at night and seek a cool, dark hiding place during the day. Best results are obtained when boards are in open areas because they provide the only source of shelter. More weevils are caught in 1+0 and fallow than in 2+0 panels.

Traps are checked every Monday, Wednesday, and Friday. Weather conditions, number, and color of adults found are recorded. The presence of tan-colored adults indicates that the population is still emerging. Most weevils are caught on hot, sunny days. In cool, cloudy weather weevils are less inclined to seek shelter. In hot weather, boards should be checked in the morning as they may heat up during the day and the weevils will move elsewhere.



The current control program consists of a surface application of acephate (Orthene) to kill the adult weevils. The aim of the program is to reduce the population before egg-laying begins. The first spray is applied 2 weeks after the adult population starts to emerge in spring and later applications may be necessary. At Surrey Nursery, acephate is not providing satisfactory control. Trials are being conducted to gain registrations for furadan (Carbofuran) which is used on strawberries and fenvalerate (Bydrin) which is used on ornamentals. A trial to control larvae with the nematode, Heterorhabditis heliothidis, a biological insecticide, was conducted at Surrey last spring (1984). The initial results are promising and work will be continued.

#### TARNISHED PLANT BUG

The tarnished plant bug, Lygus lineolaris, first caused notable damage at several nurseries in B.C. in 1983. This insect is found across North America. It is an important pest of many agricultural crops, especially alfalfa, and has a wide range of native hosts. Several species of Lygus are similar in appearance and habits, but only L. lineolaris has been identified in B.C. nurseries to date.

Adult L. lineolaris are mottled yellowish or reddish-brown, 1/4-inch (7-cm) long and half as wide, with flat, oval bodies. Lygus adults overwinter in the crowns of plants and in debris. They may be active throughout the winter in warmer climates. The adults become active the first warm days of spring, mate soon after emerging, and begin egg-laying. There are five nymphal instars (immature stages) which are greenish and resemble aphids, requiring about 3 weeks altogether. There are two to three generations a year in the Pacific Northwest and up to five in the Southern U.S. (Metcalf and Flint 1962).

These insects feed by sucking plant juices and, at the same time, introduce a toxic saliva into the plant; terminal shoots and buds are preferred. On conifers, damage to the terminals has caused stunting and multiple leaders. At affected nurseries, up to 20 percent of both container and bare-root stock has been attacked. A preference for species of pine has been observed.

Lygus damage to conifer seedlings has been confirmed in replicated caging studies. Three styroblocks containing pest-free white spruce, lodgepole pine, and interior Douglas-fir seedlings were placed in a growth chamber, and 20 adult Lygus bugs were introduced. Typical damage was observed in one week. Control seedlings experienced no damage.

Lygus are active insects and will readily move among crops. Sticky coated, non-ultraviolet-reflecting white rectangular traps hung from branches are used to monitor when bugs have invaded orchards in eastern Canada and the U.S.A. (Prokopy and others 1982).

A series of tests with these traps were conducted at several B.C. nurseries in 1984. Trials included a series of painted cardboard, sticky traps in seven shades of yellow, six shades of grey and five other colors; a series of yellow traps positioned at 1, 2, 3 and 4 feet (30, 60, 90 and 120 centimeters) above the seedlings; and a series of yellow traps placed in horizontal and vertical positions. Catches of Lygus adults were very low on all types of traps. Use of these traps is not reliable in conifer nursery culture. No pheromone has been isolated for this pest and sweep netting on conifers is not possible in the early part of the growing season because the new flush could be damaged.

Currently, foliar applications of diazinon are being used for control. Tests are being conducted with dimethoate (Cygon) which is systemic and may offer longer protection.

#### EUROPEAN MARSH CRANE FLY

The European marsh crane fly, Tipula paludosa, was introduced to the Vancouver southern B.C. area in the mid-1960's and it has since spread up the coast to Prince Rupert, to Vancouver Island, and to some parts of Washington around Puget Sound. It is unlikely to spread much farther because it is limited by moisture. T. paludosa is primarily a pest of grasses (Wilkinson and MacCarthy 1967).

Adult crane flies resemble giant mosquitoes with bodies about 1 inch (2.5 cm) long. They are brownish-grey with two transparent wings and six long, spindly legs. Adults are abundant from late August to early September; they do not feed and lay eggs immediately. The legless larvae are called leatherjackets due to their tough, grey, leatherlike skin. They live in the soil and feed almost continuously throughout the fall, and during warm periods in the winter. When it gets warmer in the spring they feed voraciously and attain their full size of about 1 1/4 inches (3 cm) by April or May. They then remain dormant until early July, when they pupate. There is one generation a year.

In B.C. nurseries, leatherjacket damage is restricted mostly to 2+0 bare-root and transplant stock because they are in the nursery during March and April when the larvae are actively feeding. Leatherjackets girdle the seedlings at soil line and may consume some of the upper roots. The damage has a neat appearance, the stem is nearly always completely ringed, and only the bark is removed. Damage has a spotty distribution with small patches of one to seven seedlings attacked throughout an infested area. Each patch is probably the work of one larva.

Leatherjackets can also attack container stock. Larvae infesting plugs often remain with the plug after the lift. No damage is evident while the seedlings are growing on the nursery, however, when the plug is planted out in the

spring the seedling may be girdled and the pest transported to new areas.

A control program should be aimed at the young larvae. They are at the most susceptible stage to insecticides and the later instars girdle seedlings. In B.C., sprays are applied about mid-October in the evening because leatherjackets browse at the soil surface at night. A single drench of diazinon is used. Most larvae wriggle to the surface before they die, so an estimate can be made of the numbers present and a kill achieved.

Only nurseries with crane fly populations are included in the program. All container stock is treated, as well as 1+0 and transplant seedlings which will be in the ground in the spring. Grassy areas around the nursery are also treated, as they could harbor reservoir populations.

#### CONIFER ROOT APHID

A conifer root aphid, Pachypappa tremulae, has been collected from several nurseries in B.C. and Alberta. Unfortunately, little is known about the life history, damage, or distribution of this aphid and its taxonomy has been confused.

Apparently, there are two stages in the life history. One is on the roots of conifers where it secretes a white, waxy substance; spruce roots seem to be preferred, however, records also exist for pine, larch, and Douglas-fir. The other life cycle stage occurs on the leaves of quaking aspen, Populus tremuloides, where leaf nests are formed. However, the leaf nest phase may not be necessary and it may survive all year on Douglas-fir or spruce (Stoyan 1975).

In conifer nurseries, P. tremulae is usually found on container spruce and spruce potted for grafting; there are few records from bare-root. The apparent preference for container over bare-root stock may be explained by the aphid's intolerance to a soil that retains water.

The white, waxy infestations are usually first noticed at lifting and look similar to mycorrhizae fungi. They are on the surface of the plug between the roots and the container wall, closer to the top of the plug than the bottom. Their distribution on the roots appears to be limited by oxygen availability.

Most nurseries with infestations of this root aphid have not reported damage because infested seedlings are not chlorotic or undersized. Damage from this insect will probably be minimal when the seedlings are growing in the nurseries with ample nutrients and moisture. Problems could arise in planting sites if the seedlings are stressed. However, soil mites and other predators may control aphids present on outplanted seedlings. Since the aphids are harmed by desiccation, some mortality may also occur during seedling lifting and sorting.

Pest management in forest nurseries is a relatively new field. As new pests are discovered they are identified, their biology investigated, and management programs are developed using all available tools including cultural, physical, biological, and chemical controls.

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EFFECTS OF WRENCHING DOUGLAS-FIR SEEDLINGS IN AUGUST<sup>1</sup>

William I. Stein

**ABSTRACT:** Effects of wrenching Douglas-fir seedlings in August of their second season in the D. L. Phipps State Forest Nursery, Elkton, Oregon, were determined by periodic samplings to learn of changes in phenological, morphological, and growth characteristics. Initial effects of wrenching moderated by January when seedlings were lifted; both unwrenched and wrenched seedlings had grown substantially larger. Survival and growth of seedlings were good during the first 5 years after outplanting, and no significant differences were found between unwrenched and wrenched seedlings.

#### INTRODUCTION

Some years ago, a study was started to determine what effect a single wrenching in August would have on Douglas-fir seedlings. At the time, wrenching was getting particular attention as a means of conditioning seedlings better for outplanting. By wrenching in early August, it appeared possible to avoid the drastic growth reductions that can result from earlier wrenching, yet favorably influence the root morphology and conditioning of Douglas-fir. Final results of that study, including a 5-year field test, are now available.

#### METHODS

A production bed of 2+0 Douglas-fir seedlings in the D. L. Phipps State Forest Nursery, Elkton, Oregon, was chosen for this test. The nursery's usual production practices, including undercutting at 15 centimeters (6 in) in late

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<sup>1</sup>This paper is based on data presented in greater detail in: Stein, William I. Wrenching Douglas-fir seedlings in August: immediate but no lasting effects. Res. Pap. PNW-317. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1984. 12 p.

April and vertical root pruning in early June, had been applied to this bed of seedlings. Bed density was about 323 per square meter (30/ft<sup>2</sup>).

On August 2, 1976, 15.2 lineal meters (50 lineal ft) of the bed were wrenched at 18-centimeter (7-in) depth with an oscillating wrenching blade. A 15.2-meter segment of the same bed with seedlings of similar size and density was left unwrenched as a control. Before dawn the next day, moisture stress in the wrenched seedlings averaged 12.25 bars, so the entire bed of seedlings was irrigated for 2 hours on August 3.

Unwrenched and wrenched seedlings were sampled on August 26, September 14, October 5, and October 29, 1976. Another sample was taken when the entire bed of seedlings was lifted on January 18, 1977. At each sampling, trees were taken from four well-spaced points in the unwrenched and four well-spaced points in the wrenched part of the bed and systematically allotted to 10-tree subsamples (bundles). Roots of bundled trees were pruned to 25-centimeter (10-in) length. Bundles of seedlings were then randomly allocated for size determination and growth tests. Following the January lifting, 100 unwrenched and 100 wrenched seedlings were planted the same day on two droughty sites near Days Creek, Oregon.

#### RESULTS

##### Development After Wrenching

Phenological and size observations were made on 40 unwrenched and 40 wrenched seedlings of each sampling. Similarities, but also some significant differences, were found between unwrenched and wrenched seedlings.

Judging from phenological appearance, growth of seedlings slowed after wrenching, then resumed more actively than did growth of unwrenched seedlings (table 1). By late August, most wrenched seedlings had developed a terminal bud compared to only one-third of the unwrenched seedlings. By early October, however, only 60 percent of the wrenched seedlings had terminal buds whereas 95 percent of the unwrenched seedlings had terminal buds. Light-green needles on more terminal shoots of wrenched than unwrenched seedlings also indicated they were more active in October. Wrenched seedlings showed a high level of root activity at every sampling date

Table 1.--Phenological status of unwrenched and wrenched seedlings at each sampling date

Phenological observation	Sampling date				
	8/26	9/14	10/5	10/29	1/18/77
<u>Percent occurrence (N=40)</u>					
Terminal bud present:					
Unwrenched	35	98	95	100	100
Wrenched	93	100	60	100	100
Terminal foliage light green:					
Unwrenched	38	10	8	8	8
Wrenched	25	3	48	0	8
Active root growth:					
Unwrenched	35	45	65	73	80
Wrenched	78	100	43	93	80

except early October, whereas root activity of unwrenched seedlings increased from August onwards.

Unwrenched and wrenched seedlings differed significantly in size in late August, 24 days after wrenching (fig. 1). Shoot length of wrenched seedlings was shorter, shoots and roots were lighter, and the number of lateral roots over 1 centimeter (0.4 in) long was less. Shoot:root ratio of wrenched seedlings was significantly larger. When lifted for planting 145 days later, however, size of unwrenched and wrenched seedlings was similar in most respects. Wrenched seedlings tended to be larger, particularly in shoot length, and have a lower shoot:root ratio.

Both unwrenched and wrenched seedlings grew substantially larger between late August and mid-January (fig. 1). For example, the oven-dry weight of roots of wrenched seedlings increased fivefold; for unwrenched seedlings, about half that much. Shoot dry weight of wrenched seedlings increased by a factor of 2.4, of unwrenched seedlings by 1.6. These size changes appear to be more than random variation among successive destructive samplings. Regression analyses showed that there was a significant change with time in each observed attribute for both wrenched and unwrenched seedlings with one exception--shoot length of unwrenched seedlings.

#### Growth of Tended Seedlings

Survival and growth observations were made on 20 unwrenched and 20 wrenched seedlings potted promptly after each lifting and an equal number that were planted in raised outdoor

beds. Potted seedlings were initially placed in a greenhouse and later outdoors, and both sets of seedlings were tended for more than a year.

Time of lifting as well as wrenching influenced subsequent phenology and growth of tended seedlings (table 2). Survival of wrenched seedlings was generally slightly higher. In outdoor beds, unwrenched seedlings from the August, September, and October liftings were darker green the following March than were wrenched seedlings lifted in the same 3 months. Among potted seedlings, only unwrenched and wrenched seedlings lifted in January flushed and started growing promptly. Potted seedlings of the other four liftings needed a chill period before most of their terminal buds would flush. In the outdoor beds, seedlings of the January lifting also flushed earliest and most vigorously.

Table 2.--Survival and shoot growth of unwrenched and wrenched seedlings lifted at different dates and transplanted to pots and outdoor beds

Seedling response	Date lifted				
	8/26	9/14	10/5	10/29	1/18/77
<u>IN POTS</u>					
Seedlings alive (%)					
Unwrenched	95	90	90	89	95
Wrenched	85	100	100	100	100
Average shoot growth (cm):					
Unwrenched	3.1	3.6	3.5	5.9	10.3
Wrenched	2.4	2.6	3.0	4.3	9.4
Increment gained (%)					
Unwrenched	14	14	18	24	41
Wrenched	11	10	13	18	37
<u>IN OUTDOOR BEDS</u>					
Seedlings alive (%)					
Unwrenched	80	80	95	90	95
Wrenched	100	100	90	100	100
Average shoot growth (cm):					
Unwrenched	8.8	9.2	9.4	9.7	10.1
Wrenched	7.1	7.7	8.0	10.0	11.5
Increment gained (%)					
Unwrenched	46	39	39	48	47
Wrenched	31	32	31	50	44



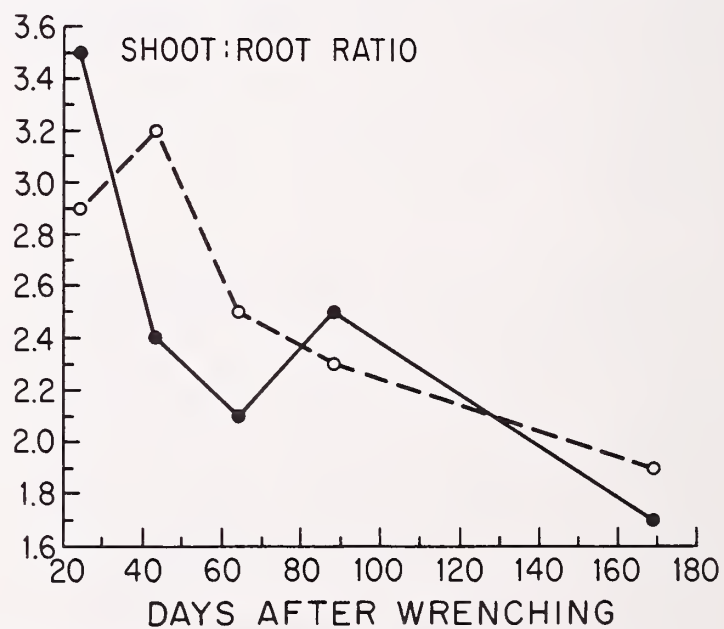
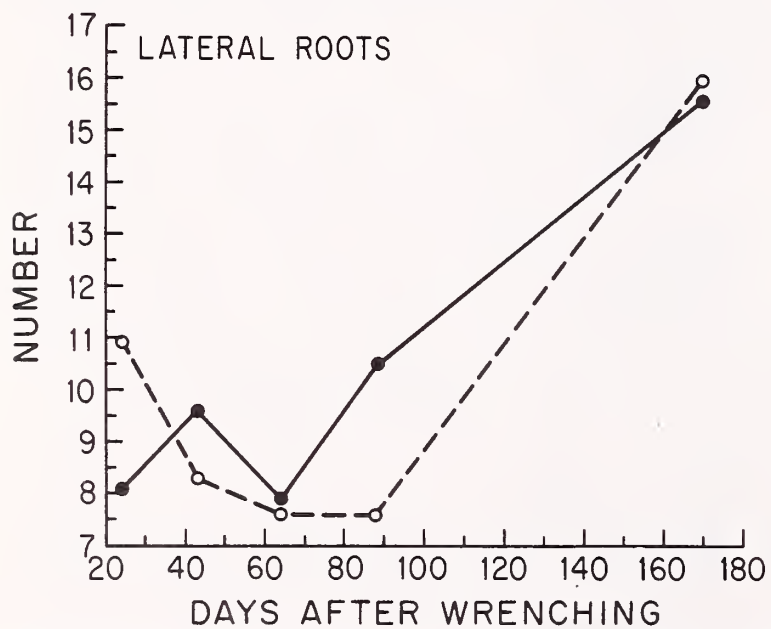
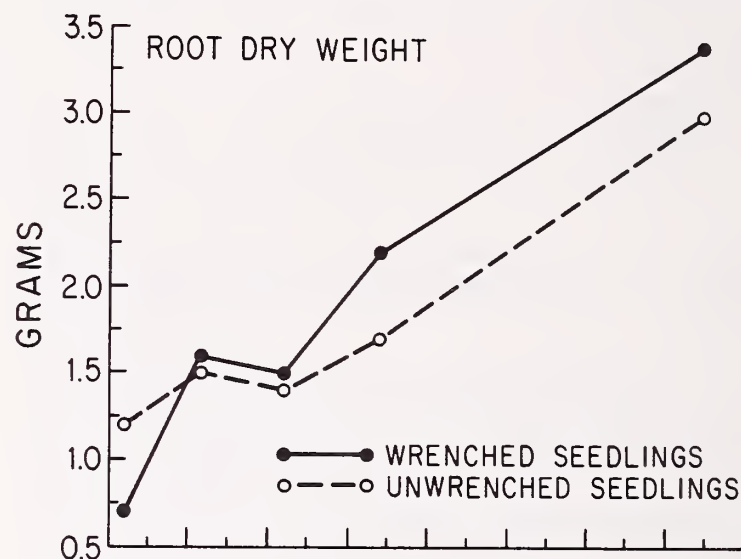
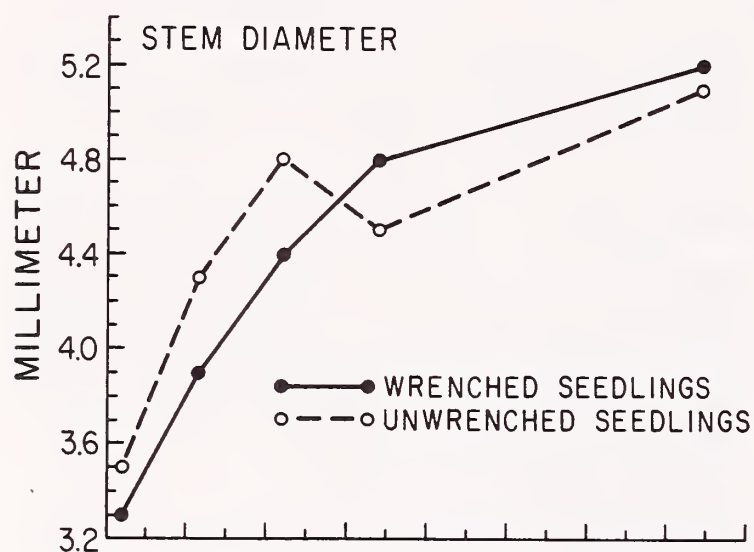
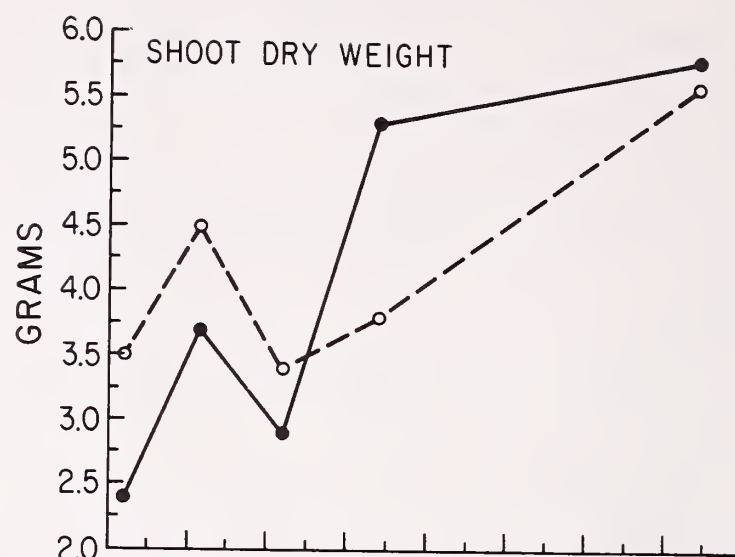
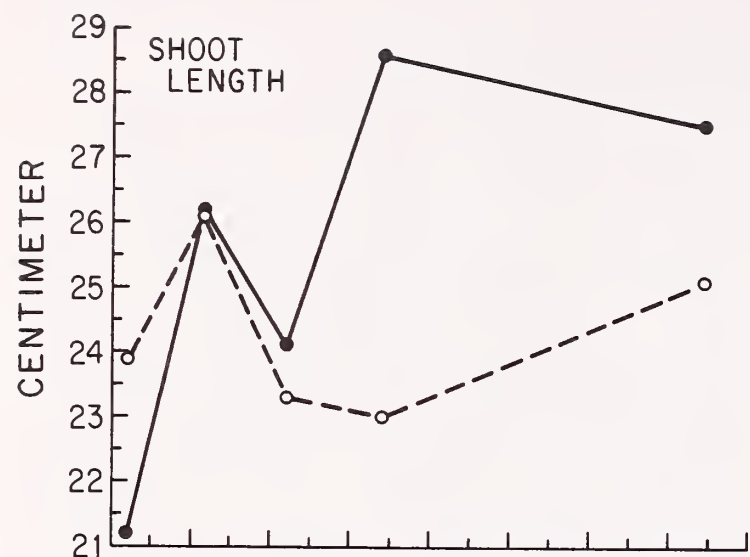


Figure 1.--Size and weight of unwrenched and wrenched seedlings at successive samplings from August to January.

The later that both wrenched and unwrenched seedlings were lifted, the greater their subsequent height growth (probability greater than 99 percent). An adverse effect of wrenching on height growth was indicated for the earlier liftings, but growth differences for unwrenched and wrenched seedlings later narrowed.

#### Growth in the Field

Two hundred seedlings from the January lifting were planted the same day on a steep southeast and northeast site located southeast of Roseburg, Oregon. On each site, 100 trees were planted at 2.4-meter (8-ft) spacing in a 10x10 grid. Wrenched trees were planted at half the planting spots and unwrenched trees at the rest as randomly designated in advance. Survival and total height of trees were determined periodically.

Field survival and total height of unwrenched and wrenched seedlings did not differ significantly after 5 years (table 3 and fig. 2). Survival of wrenched seedlings averaged 89 percent; of unwrenched seedlings, 86 percent. Total height averaged 97.8 centimeters (38.5 in) and was identical for unwrenched and wrenched seedlings. Stem diameter 30 centimeters (12 in) above ground level averaged 14.1 millimeters (0.6 in) for unwrenched seedlings and 13.1 millimeters (0.5 in) for wrenched seedlings; the difference was not significant at the 90-percent probability level.

Table 3.--Survival and stem diameter of unwrenched and wrenched seedlings 5 years after planting

Seedling attribute	Slope		
	Southeast	Northeast	All
Survival (%):			
Unwrenched	88	84	86
Wrenched	92	86	89
Average	90	85	87.5
Stem diameter (mm):			
Unwrenched	14.7	13.5	14.1
Wrenched	13.1	13.1	13.1
Average	13.9	13.3	13.6

#### DISCUSSION AND CONCLUSIONS

Results of this study add some insight to the debate on the merits of wrenching for improving field survival and growth of

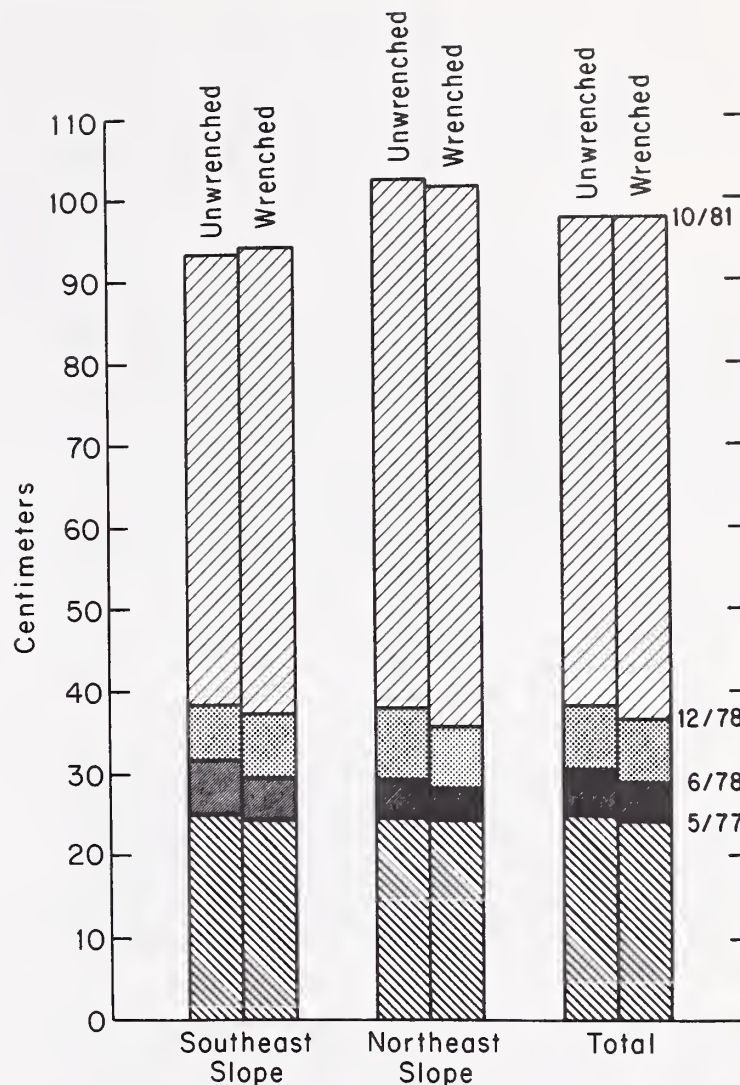


Figure 2.--Total height of unwrenched and wrenched Douglas-fir seedlings at intervals after planting.

Douglas-fir. Even a single wrenching late in the season curtailed seedling growth and altered the size and physiology of Douglas-fir seedlings, a finding consistent with those from other, generally more drastic, wrenching regimes. The effects of wrenching did not improve field survival or growth of seedlings, a finding consistent with those of some investigators but not of others.

The interwoven effects of lifting date and wrenching deserve particular attention for several reasons:

1. The more time that elapses between wrenching and lifting, the more likely wrenching effects will be diminished because of growth and physiological changes occurring in both wrenched and unwrenched seedlings.
2. Lifting seedlings too early interrupts their development and may affect their subsequent performance more than wrenching does.
3. Instead of conditioning seedlings for lifting, wrenching in August appeared to have had the opposite effect; it stimulated late growth under the prevailing conditions.



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LIGHT REDUCTION AND MOISTURE STRESS:

EFFECTS ON CONTAINERIZED WESTERN LARCH SEEDLINGS

Nan C. Vance

**ABSTRACT:** Morphological and physiological responses of western larch were determined by applying three shade and three moisture stress treatments in late summer to 10-week-old seedlings. Moisture stressing reduced height and diameter of unshaded seedlings. Unshaded and unstressed seedlings had the greatest shoot and root dry weight and the lowest shoot/root ratios. Terminal bud set occurred under a 14-hour photoperiod.

INTRODUCTION

Although its range is restricted to the Columbia Basin, western larch (*Larix occidentalis* Nutt.) is a valuable commercial species. This highly intolerant species grows best under the full sunlight of clearcuts yet suffers high mortality in the seedling stage because of drought (Schmidt and others 1976).

A major goal in rearing conifer seedlings is to produce seedlings morphologically and physiologically suited for withstanding the rigors of planting and harsh site conditions (Tinus and McDonald 1979). Meeting that objective is difficult with western larch because, atypically, it is a deciduous conifer with relatively unstudied physiological requirements. The use of shade and moisture stress to induce dormancy or to stop height growth in larch seedlings is commonly practiced without knowledge of how or if these treatments produce the desired response.

The objective of this study was to see if manipulating the greenhouse environment would produce measurable differences in seedling response. Moisture stressing and shading were applied, and their effects on height, diameter, dry matter accumulation and distribution, and timing of bud set were measured.

MATERIALS AND METHODS

Western larch seed randomly selected from a seed lot of the Montana State Department of Lands were

collected in 1980 from about 4,000 ft (1,200 m) elevation and 48°35' latitude and placed in cold storage. All seed were stratified for 23 days, sown in plastic tubes, and grown in the Montana State Nursery greenhouse, Missoula, Montana, during the spring and summer of 1982. The resulting seedlings were grown in a peat-vermiculite medium and under controlled environmental conditions in an operational greenhouse: 85/68°F (30/20°C), 50 to 80 percent RH with a 24-hour photoperiod by supplemental lighting. All seedlings were watered by an overhead sprinkling system and fertilized with a commercial fertilizer (9-45-15 and 20-20-20). At the end of July when the seedlings were about 10 weeks old, a set of 15 randomly sampled seedlings was harvested and baseline measurements of height, stem diameter (measured above the root collar), and shoot and root oven-dry weight were determined. Supplemental photoperiod lighting was discontinued and further treatments were applied to the remaining seedlings.

Two shade treatments were applied by using commercial shade cloths: one provided 37 percent and the other 27 percent of full sunlight. Each shade shelter covered 600 seedlings (three container trays); another 600 were left uncovered for the treatments with no shade (full greenhouse light, i.e., 70 percent of full sunlight).

After all seedlings were watered to saturation, a subset of 200 seedlings from each light treatment was given one of three moisture stress treatments. One subset was watered at a frequency such that predawn seedling water potential ( $\psi$ ) was above -0.4 MPa (unstressed). Water was withheld from another subset until predawn  $\psi$  reached -0.7 to -1.2 MPa (moderate stress), and from a third set until predawn  $\psi$  reached -1.5 to -1.8 MPa (severe stress). Seedling stress development was monitored with a pressure chamber by measuring  $\psi$  on sampled seedlings clipped above the root collar (Ritchie and Hinckley 1975). The stress treatments involved two consecutive drying cycles, each taking from 1 to about 2 weeks to complete. During the stress cycling, fertilizer was withheld so as not to confound the effects of the moisture stress treatments. Morphological changes and date of bud set were noted.

At the end of the period (August 16), 15 seedlings from each treatment were harvested and height, diameter, and shoot and root dry weights were measured. The remaining seedlings were subsequently fertilized at weekly intervals with 5-11-26, and greenhouse temperatures were lowered to 77/55°F (25/13°C). The seedlings were moved outside by the end of September, and final data

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were taken the first week in October. Shoot dry weights could not be measured because of extensive needle drop.

Data were subjected to an ANOVA. Significant differences in treatment effects were determined by Duncan's multiple range test.

## RESULTS AND DISCUSSION

### Growth and Morphology

Mean heights of the seedlings harvested on August 16 and on October 15, 1982, are presented in table 1. Because of the variability within treatments, the effects of light reduction on height were not statistically significant at the 0.05 level of confidence. Rehfeldt (1982) found height variability within genetic populations and attributed it to the exogenous nature of shoot growth in western larch. In the present study, however, statistically significant differences in height were detected among moisture-stressed seedlings receiving the most intense light treatment.

Although bud formation was visible before August 16, there was measurable height growth of about 0.8 in. (2 cm) among the unstressed seedlings between August 16 and October 5 (fig. 1). This growth may have been due to the continual or "free growth" habit of western larch (Rehfeldt 1982; Owens and Molder 1979) and to the late seasonal growth characteristic of *Larix* species (Ledig and Botkin 1974). However, height growth almost ceased in the stressed seedlings.

Light reduction significantly decreased mean diameter of seedlings harvested October 5 (table 1). Moisture stress, however, did not except for the stressed seedlings under full light.

A fungus, *Botrytis cinerea*, infected seedlings in September, causing considerable needle drop. Therefore, shoot dry weights were determined only on seedlings harvested August 16. Among severely stressed seedlings, dry weight differed significantly between those shaded and unshaded (table 1).

Root dry weight was significantly greater among unshaded seedlings than among shaded ones, regardless of moisture stress (table 1). The relative increase in allocation of dry matter to roots by October was greatest in unstressed seedlings grown under full light (fig. 1). The increase in root dry weight with increasing light intensity was linearly correlated ( $r^2 = 0.68$ ,  $n = 135$ ). This relationship has also been found in other coniferous species by Fairbairn and Neustein (1970) and Logan (1966).

Shoot/root ratios were calculated from seedlings harvested August 16 (table 1). Within the unstressed and moderately stressed treatments, shoot/root ratio was significantly greater for seedlings grown under 27 percent light than for those in the other two light treatments; however, there was no difference as a result of moisture stressing. The unshaded treatment with no moisture stress resulted in seedlings with the highest mean total weight (0.642 g) and the lowest mean shoot/root ratio (1.74).

### Dormancy Induction

Terminal buds first appeared on August 13 when daylength was approximately 14 hours. Vaartaja (1959) found that in 1-year-old eastern larch seedlings from as far south as 46° latitude, critical daylength for terminal dormancy was also 14 hours. In the present study, no significant differences in time of terminal bud set were

Table 1.— Morphology and dry matter accumulation and distribution in the test seedlings, by harvest date, moisture stress, and light treatment.

Harvest date & moisture stress	Height (cm) according to % full light			Diameter (cm) according to % full light			Shoot dry weight (g) according to % full light			Root dry weight (g) according to % full light			Shoot/root ratio according to % full light		
	70	37	27	70	37	27	70	37	27	70	37	27	70	37	27
August 16															
None	13.6a	12.8a	12.7a	.20a	.18b	.17b	.405a	.345a	.352a	.237a	.182b	.171b	1.7a	1.9ab	2.1b
Moderate	12.4a	12.8a	12.5a	.17a	.18a	.17a	.357a	.354a	.321a	.203a	.162b	.132b	1.8a	2.2b	2.4b
Severe	12.5a	12.5a	12.6a	.19a	.16a	.15a	.387a	.322b	.291b	.209a	.161b	.139b	1.9a	2.0a	2.1a
October 5															
None	15.8a	15.1a	14.9a	.25a	.21b	.20b	—	—	—	.559a	.355b	.285c	—	—	—
Moderate	12.7a	13.7a	13.8a	.24a	.21b	.19b	—	—	—	.537a	.343b	.267c	—	—	—
Severe	13.2a	14.1a	13.9a	.23a	.20b	.20b	—	—	—	.509a	.343b	.241c	—	—	—

Note: Values connected by vertical brackets in a column (moisture treatments) and values followed by the same letter within a row (light treatments) are not significantly different ( $P < 0.05$ ) according to Duncan's multiple range test. Values for moisture treatments are discrete by date, and those for light treatments are discrete by seedling parameter.



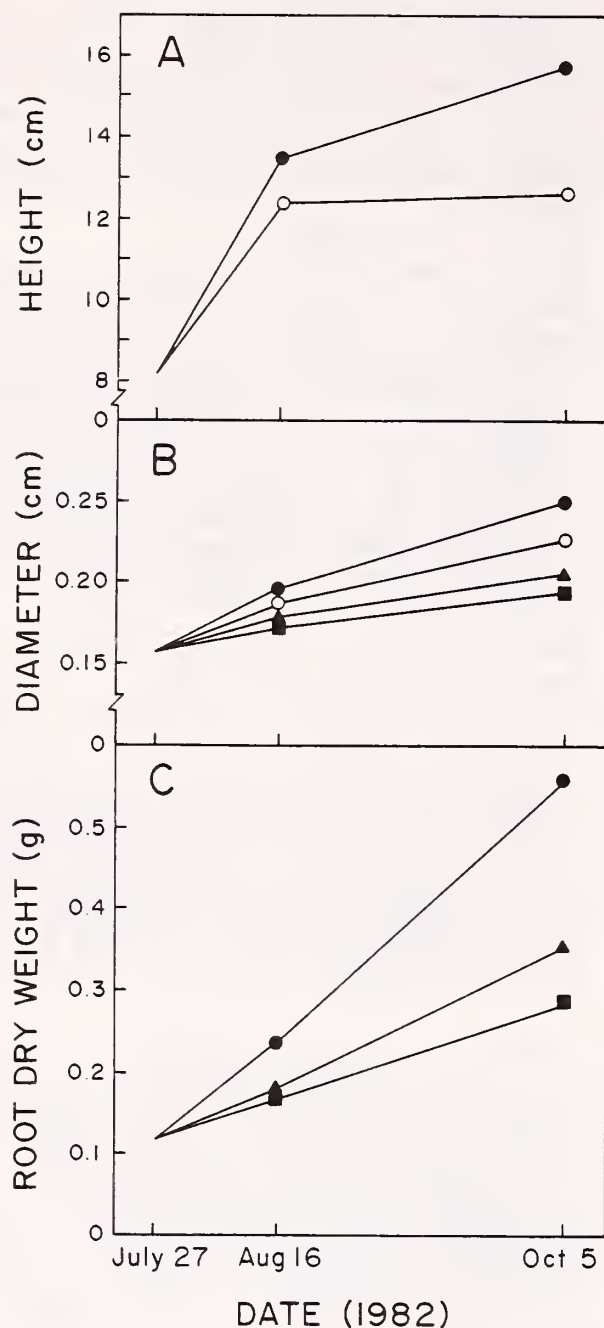


Figure 1.--(A) Change in height of unstressed (●) and stressed (○) western larch seedlings under 70 percent of full sunlight; (B) change in diameter of unstressed and stressed seedlings under 70 percent of full sunlight and of unstressed seedlings under 37 percent (▲) and 27 percent (■) of full sunlight; and (C) change in root dry weight of unstressed seedlings under all light treatments. Each point is the mean of 15 measurements.

detected among the various treatments: terminal buds were visible on virtually all seedlings within 72 hours. Although buds in greenhouse-grown western larch seedlings often rebreak, these were the final resting buds of the season. Photoperiod was a more critical factor than light intensity or moisture stress in inducing a final resting bud and dormancy under the environmental conditions of this study.

#### CONCLUSIONS

The variability in height among the test seedlings suggests that this parameter is not pre-

dictable for western larch and that less emphasis should be placed on it as an attribute of seedling quality. Nevertheless, seedling height growth decreased as moisture stress became more severe. If seedlings are not stressed, height growth may continue after bud set. The direct relationship of root dry weight to light intensity and the dramatic increase in root dry weight late in the growing season under relatively intense light suggests that shading larch after bud set is not desirable. In general, the most intense light produced the heaviest seedlings with the lowest shoot/root ratios, but not necessarily with the greatest height.

Onset of bud set was not influenced by moisture stressing or by reduction of light intensity but by the 14-hour photoperiod. This relationship suggests that while moisture stressing may induce a temporarily resting bud in larch, truly dormant buds could best be induced by photoperiod control.

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**ABSTRACT:** Confusion exists with regard to organic matter levels that should be maintained in forest nurseries. Factors influencing organic matter depletion are discussed. A method of setting realistic goals is presented and explained using a case study from the Placerville Forest Nursery.

## INTRODUCTION

The importance of organic matter is generally accepted by the majority of nursery managers. There is, however, considerable confusion concerning the level of organic matter that should be maintained in the soil. Results of the OSU Nursery Survey (Davey 1984) showed that 86% of the nursery managers responding felt that their organic matter levels were not as high as they should be. They reported levels ranging from 1 to 7% (average 3.6%) but felt that levels should range from 2 to 10% (average 5%). Sixty-two percent rated organic matter maintenance among the top five management problems.

It would appear that there is no clear idea of how much is enough. Forest nursery management is basically a mining operation with regard to organic matter. The removal of whole seedlings plus the numerous cultural activities that accelerate the organic matter decomposition process hasten the depletion of soil organic matter.

## FACTORS INFLUENCING ORGANIC MATTER LEVELS

The level of organic matter that can be maintained in a forest nursery is influenced by the same factors that determine the amount of native organic matter present in an "undisturbed" forest soil plus the cultural practices used in the nursery.

The amount of organic matter in an "undisturbed" forest soil is a function of the decomposition of forest litter and the synthesis of humus or soil organic matter. The rate at which this process proceeds and the amount of humus formed is influenced by moisture, temperature, and soil texture.

Moisture and temperature influence the rate of decomposition. The specific surface that will complex organic matter is a function of soil texture. Under similar climatic conditions higher levels of organic matter will occur in fine-textured soils than in coarse-textured soils.

It is unrealistic to set a level or range in levels that should be maintained in all nurseries regardless of location. What then is realistic or practical? This should be determined for each individual nursery. In practice this has not been done.

## A SUGGESTED APPROACH

A logical approach to determining a realistic level of organic matter to be maintained would be to ascertain the level in a soil similar to the nursery soil that is supporting a relatively undisturbed forest stand. This level would need to be discounted to account for cultural practices. Jenny (1941) reported that 38% of the native organic matter was lost over a period of 50 years of cultivation. Nursery cultural practices including land levelling, frequent cultivation, and whole plant lifting also influence loss of organic matter. A total loss of 40% would be a conservative estimate.

## PLACERVILLE NURSERY - A CASE STUDY

In the course of making an intensive soil survey and developing a soil management plan for the U.S. Forest Service Placerville Nursery, an Aiken loam similar to the nursery soil, but supporting a well-stocked stand of ponderosa and sugar pine and white fir was sampled. Elevation and rainfall are the same as at the nursery. Undecomposed litter was removed and the mineral soil was sampled to a 7-inch depth, the same depth as used for routine nursery soil sampling. Organic matter was determined by the Oregon State University Soil Testing Laboratory. The average soil organic matter in the stand sampled was 10.3%. It would be unrealistic to assume that this level could or should be maintained at the nursery.

Much of the land in the Placerville area was cleared in the early 1900's, put into grain production and eventually into orchards. All of the nursery acreage was in orchard production at the time of acquisition. If it is assumed that at the time of clearing the native organic matter was 10 percent and that 38% was lost through cultivation the resulting level would be 6.2%.

Paper presented at combined meeting of the Western Forest Nursery Council and Intermountain Nurseryman's Association, Coeur d'Alene, ID, August 14-16, 1984.

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The average level for all of the nursery blocks sampled was 4.9% and ranged from 3.6 to 6.6%. The difference between 6.2 and 4.9% percent may have resulted from erosion losses during orchard production, orchard clearing, and land levelling for nursery production and from whole tree lifting. A level of 5.5 to 6.0% would probably be an attainable goal.

Organic Matter Management -- In the parcels having 5.0% or more organic matter, a large biomass green manure crop in each rotation would help to maintain current levels.

In parcels below the 5.0% level, additions of organic materials such as sawdust could be utilized. A 2-inch layer of sawdust per acre is approximately 20 tons or 40,000 pounds. Assuming 2,000,000 pounds for the weight of an acre furrow slice (7 inches) of soil this would be an addition of 2% organic matter. During a three-year rotation approximately 90% of the sawdust will decompose resulting in an increase of 0.2 percent organic matter. On areas having low organic matter levels this would increase the rate of attaining the desired level. When adding sawdust, 10 pounds of nitrogen should be added per ton of sawdust, half of it when the sawdust is turned under and the second half at a time that fits into the management schedule.

Sawdust or other highly carbonaceous materials should not be applied just prior to seedbed preparation and seeding a new crop. After lifting and just prior to establishing a green manure crop is probably the best time. The application of other nutrients and lime, if needed for the next seedling crop, would enhance the decomposition process and produce a heavier green manure crop.

Although the addition of sawdust has been used as an example for increasing soil organic matter there are other materials that can be used. Materials which have not been used previously should not be used on a large scale without some small area applications for testing their quality. It is strongly suggested that steps be taken to establish realistic goals for maintenance of soil organic matter.

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## MEETING NOTES

### MESSAGE FROM CHAIRPERSON

An excellent turnout coupled with good weather and an attractive setting helped to make the conference an enjoyable three days. Forty well-presented papers made it informative as well as enjoyable. I thanked all of you and gave special thanks and recognition at the wrap-up. You were all terrific. We registered 199 people and that is noteworthy. Our conferences have enjoyed outstanding attendance for a number of years and that speaks for itself.

To repeat what Frank stated in 1982. Please pre-register for the meetings in Fort Collins and in Olympia. It goes a long way in helping your hosts to provide well for you. Looking forward to seeing you in 1985 and 1986.

--Darrell A. Benson

### MINUTES FROM THE BUSINESS MEETING

The meeting was chaired by Darrell Benson. The minutes of the 1982 Western Nurserymen's Conference held in Medford, Oregon, were referred to and accepted as printed in the Proceedings; motion to accept by Jim Sedore, and seconded by Patricia Malone.

By popular demand this business meeting is being held midway through the three-day session (as opposed to holding it the last part of the last day).

The 1985 Intermountain Nurserymen's Association Meeting will be hosted by the Colorado State Forest Service, Martin Strachan, Chairperson. Marv explained that everything was preliminary at present, but the plans are to hold it August 20-22, 1985. Marv pointed out that the National SAF Meeting was being held at Fort Collins during this same time. Fort Collins does not have an airport, but limo service is available from the Denver Airport.

The 1986 Western Forest Nursery Council Meeting is scheduled to be co-hosted at Olympia, Washington, by Weyerhaeuser, IFA, and Washington DNR. Jim Bryan, Weyerhaeuser, advised there are approximately 75 MM seedlings grown and sold out of Olympia each year.

Jim Sedore, Washington DNR, suggested the following items for consideration and future discussion:

1. Should we have the meeting later in the year (October or November). We would have a full year's data by these dates.
2. We could have users come and present their problems (tree planters, etc.).
3. Run parallel agendas: "Wet growers meeting;" "Dry growers meeting."
4. Set a theme.
5. If anyone would like to hear a special topic (at the '86 meeting), let them know in advance.

The 1988 meeting was discussed insofar as who would host it. As previously set up in the schedule, the B.C. Forest Service would be next in line. Ralph Huber, B.C. Forest Service at Victoria, will advise if they will be able to host it. If they are unable to, Randy Selig, Oregon State Forest Nursery in Elkton, Oregon, would like to do so. This offer was moved to accept by Rex Eide and seconded by Ron Adams.

The Intermountain Nurserymen's Association Meeting will be in Oklahoma in 1987. Frank Morby pointed out the name of the Intermountain Session needs to be changed to Intermountain Nursery Managers Meeting.

Tom Landis, S&PF Denver, indicated we may have to decide how we will finance the publication of the Proceedings if S&PF funds dry up. One suggestion would be to tack on a fee with the registration or add a line item (at the attendee's option) to receive the publication. If we want the Proceedings published in a retrievable fashion, it will have to be on a fee basis. A show of hands indicated they should be printed (with an additional "reasonable" fee collected) so as to be retrievable. This is a contingency plan if the funds cannot support the costs. Tom Landis volunteered to look into options. Mary Duryea, OSU, and Jim Sedore offered to assist them. Ron Adams acknowledged Tom Landis for the super job he has done in getting materials together in an orderly manner for the publications of the Proceedings.



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Landis, Thomas D., compiler. Proceedings: Western Forest Nursery Council-Intermountain Nurseryman's Association combined meeting; 1984 August 14-16; Coeur d'Alene, ID: General Technical Report INT-185. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 140 p.

Contains 34 papers describing successful practices at nurseries in the western United States and Canada, and research aimed at providing new management possibilities. Emphasis is on conifer species.

KEYWORDS: seed germination, seedling planting and lifting,  
forest nursery practices, containerized seedlings,  
forest nursery production

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The Intermountain Research Station, headquartered in Ogden, Utah, is one of eight Forest Service Research stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station's primary area includes Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

Several Station research units work in additional western States, or have missions that are national in scope.

Field programs and research work units of the Station are maintained in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Ogden, Utah

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)

